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Three Reports Concerning the Tortugas Sanctuary Studies, 1981-1982

Report I. The Tortugas Sanctuary Study, May 1981-February 1982; Edward F. Klima and Thomas Costello.

Report II. A Preliminary Analysis of Pink Shrimp (Penaeus duorarum) Size and Abundance During the Tortugas Shrimp Sanctuary Study, September 1981-February 1982; Terrell W. Roberts.

Report III. A Synopsis of the Tortugas Pink Shrimp Fishery, 1960-19681, and the Impact of the Tortugas Sanctuary; Edward F. Klima, Geoffrey A. Matthews, Frank J. Patella.

U. S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Dr. John V. Byrne, Administrator

National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

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REPORT II

A PRELIMINARY ANALYSIS OF PINK SHRIMP (PENAEUS DUORARUM) SIZE AND ABUNDANCE DURING THE TORTUGAS SHRIMP SANCTUARY STUDY, SEPTEMBER 1981 - FEBRUARY 1982

BY

TERRELL W. ROBERTS

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around Stations F10, F13, F14, and F17. The mean size of the shrimp caught commercially usually was equivalent to the mean size of shrimp found at the closest station, but the CPUE for each commercial tow generally was less than the CPUE at the nearest sampling site. Because larger shrimp bring higher prices, the captain tried to select those locations that had a higher abundance of large shrimp. To this end, he was successful for 54 of the 70 commercial tows (77% of the time) made during the six cruises.

Salinity and temperature were measured at each station at the surface and near bottom. There was very little variation in either parameter. Except on a few occassions, salinity was mostly 34 o/oo - 36 o/oo during all six months. Anomalously low salinity and temperature readings were recorded at Station F23 in November and probably should be considered as recording errors. Temperature was also stable from surface to bottom, varying only 1.7°C during any one cruise, except September when the variability was 3°C. Temperature was highest in September (28°C average) and lowest in January (20.5°C average).

Ovarian development during the six month study period followed the trends reported in previous studies. Development indicating reproductive activity was highest during the warmest months (September and October) and lowest during December. January was slightly colder than December, but it also represents the start of the sping peak in spawning activity. Therefore, there was a higher proportion of advanced ovarian development during January when compared to December, and it increased again in February.

ABSTRACT

Twenty-three stations located inside and outside the Tortugas Shrimp Sanctuary were sampled once a month (September 1981 to February 1982), primarily for abundance and length/frequency data on the pink shrimp, Penaeus duorarum. The collection of data on shrimp ovarian development and temperature and salinity data were secondary objectives. Four nets were towed simultaneously for 30 minutes at each station. A complex and variable distribution of shrimp abundance and size was found in the study area.

Shrimp size tended to increase in an east to west direction during September and October. During November, this pattern changed with the largest shrimp at the middle stations and smaller shrimp at the eastern and western ends. December was an anomalous month compared to the other months since there were very few small shrimp (<103 mm total length) in the population. The mean size of the shrimp at all stations in December was ≥106 mm. January and February show a reversal of the earlier trend with small shrimp mostly at the western stations and larger shrimp at the eastern end. Small shrimp dominated the entire population, except in December when they seemed to almost disappear from the study area. Although most of the population of small shrimp was inside the sanctuary, they were also found outside the line and even dominated the population there in January and February.

Shrimp abundance, defined as catch per unit effort (lbs-heads on/net/30 min. tow), was highly variable. The highest CPUEs occurred inside the sanctuary and a general inverse relationship existed between CPUE and mean length. The highest CPUEs generally occurred at Stations F10, F13, F14, and F17.

Commercial tows by the MV MISS VIRGINIA were permitted after regular sampling was accomplished. These tows usually clustered

INTRODUCTION

The Gulf of Mexico Fishery Management Council (GMFMC) has the responsibility for developing a shrimp fishery management plan for the Gulf of Mexico. This plan for managing six species of shrimp was adopted in 1980, and it is reviewed annually to evaluate management measures for fairness and effectiveness in optimizing fishery yield (Gulf of Mexico Regional Fishery Management Council, 1980). One of the management measures adopted by the GMFMC was the establishment of a cooperative permanent closure with the State of Florida and the U.S. Department of Commerce in an area near the Dry Tortugas to protect small pink shrimp (Penaeus duorarum Burkenroad) until they attain a size range generally larger than 69 tails per pound. This closed area shown in Figure 1, known as the "Tortugas Shrimp Sanctuary," had coordinates established in 1974 based on previous research that showed a direct relationship between size of shrimp and depth of water (e.g., Ingle et al., 1959; Iversen et al., 1960). However, other investigators have shown that there is no simple movement of larger shrimp to deeper water outside the sanctuary nor is there segregation of pink shrimp by size (Eldred et al., 1961). Although there is a general net movement to deeper water, size frequency analysis (Ingle et al., 1959; Iversen et al., 1960) and tagging studies (Iversen and Idyll, 1960; Iversen and Jones, 1961) have found a random or back and forth movement of shrimp along a northerly or north-westerly axis. These studies indicated that, either seasonally or all year, small and large pink shrimp may occur together inside the sanctuary.

In order to allow commercial fishermen to harvest the larger shrimp in the deeper waters within the sanctuary, the boundaries of the Tortugas Shrimp Sanctuary were redefined in 1981 (Fig. 1) so that, in general, all water inside the closed area was less than

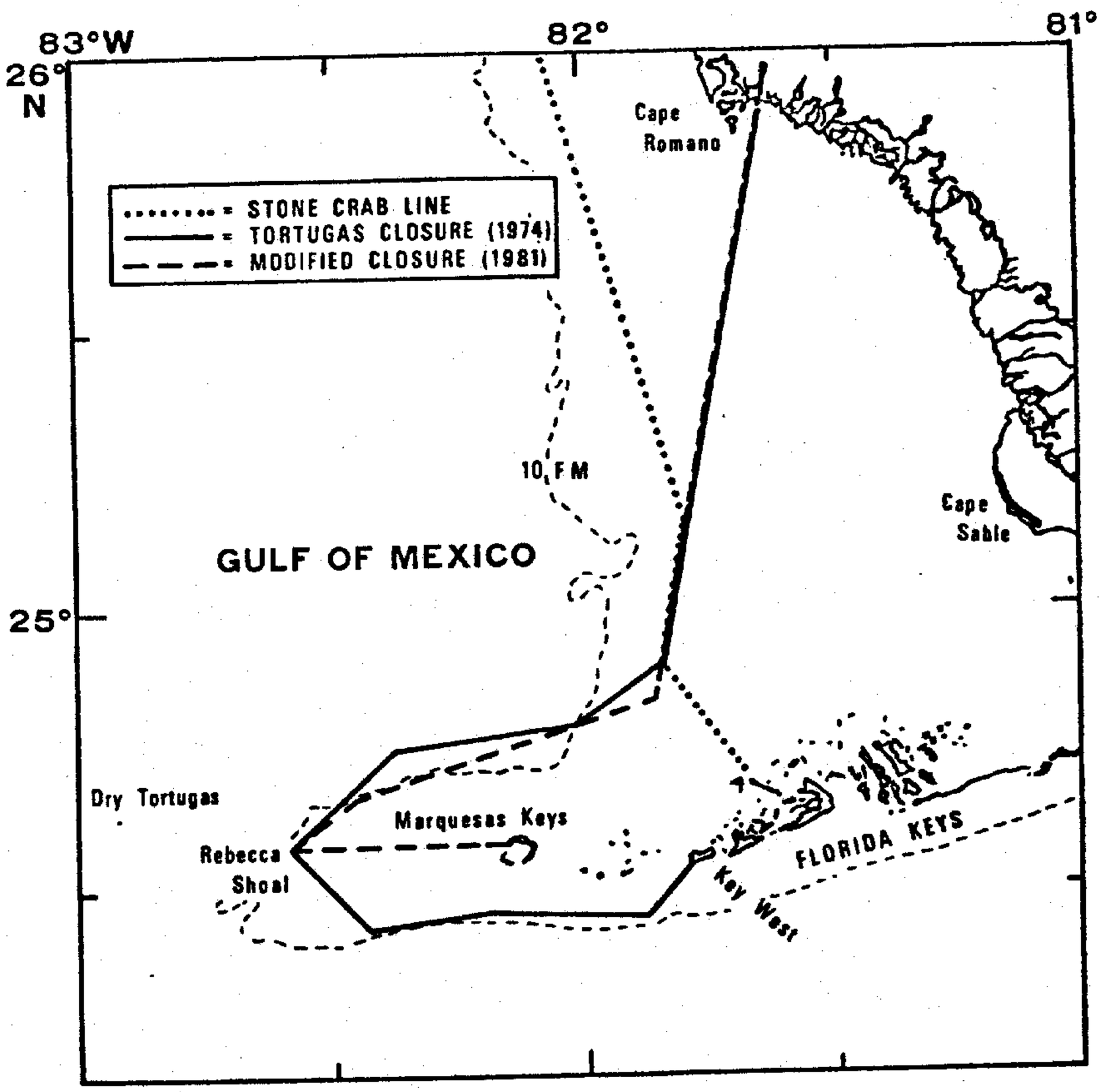

Figure 1. Map of the Tortugas area showing the stone crab line, shrimp sanctuary boundaries of 1974, and the 1981 modified sanctuary boundaries.

10-11 fathoms deep. However, the Council recognized the need for current data on which to delineate the sanctuary boundaries. Thus a sampling program was recommended to more precisely define the actual range of small shrimp in the Tortugas area.

To this end, a sampling program was initiated in September 1981 by the Galveston Laboratory of the National Marine Fisheries Service (NMFS) and funded by GMFMC to provide data on shrimp size inside the sanctuary boundary. The program was originally set for monthly sampling over a six month period (September 1981 - February 1982), but was extended for six months in March 1982 to provide a full year's data. The objectives of the study were to:

(1) Collect length/frequency data on pink shrimp within and outside the Tortugas Shrimp Sanctuary;

(2) collect ovarian development data on female pink shrimp within the study area;

(3) collect data on fish and crustacean by-catch associated with the Tortugas pink shrimp community; and

(4) characterize hydrographic parameters of the study area.

This report will be limited to the results of data analysis for the first six months of sampling and any conclusions on pink shrimp populations in the Tortugas area must necessarily be limited in scope until the full year's data have been collected and analyzed.

METHODS AND MATERIALS

The MV MISS VIRGINIA, a 23.2 m (76 ft) Florida trawler, was contracted by NMFS to conduct all sampling activities for the Tortugas Shrimp Sanctuary study. Twenty-four stations selected randomly on trawlable bottom and ranging in depth from 6 to 14 fathoms were located inside and outside the sanctuary boundary (Fig. 2). The MV MISS VIRGINIA, rigged for twin trawling with four

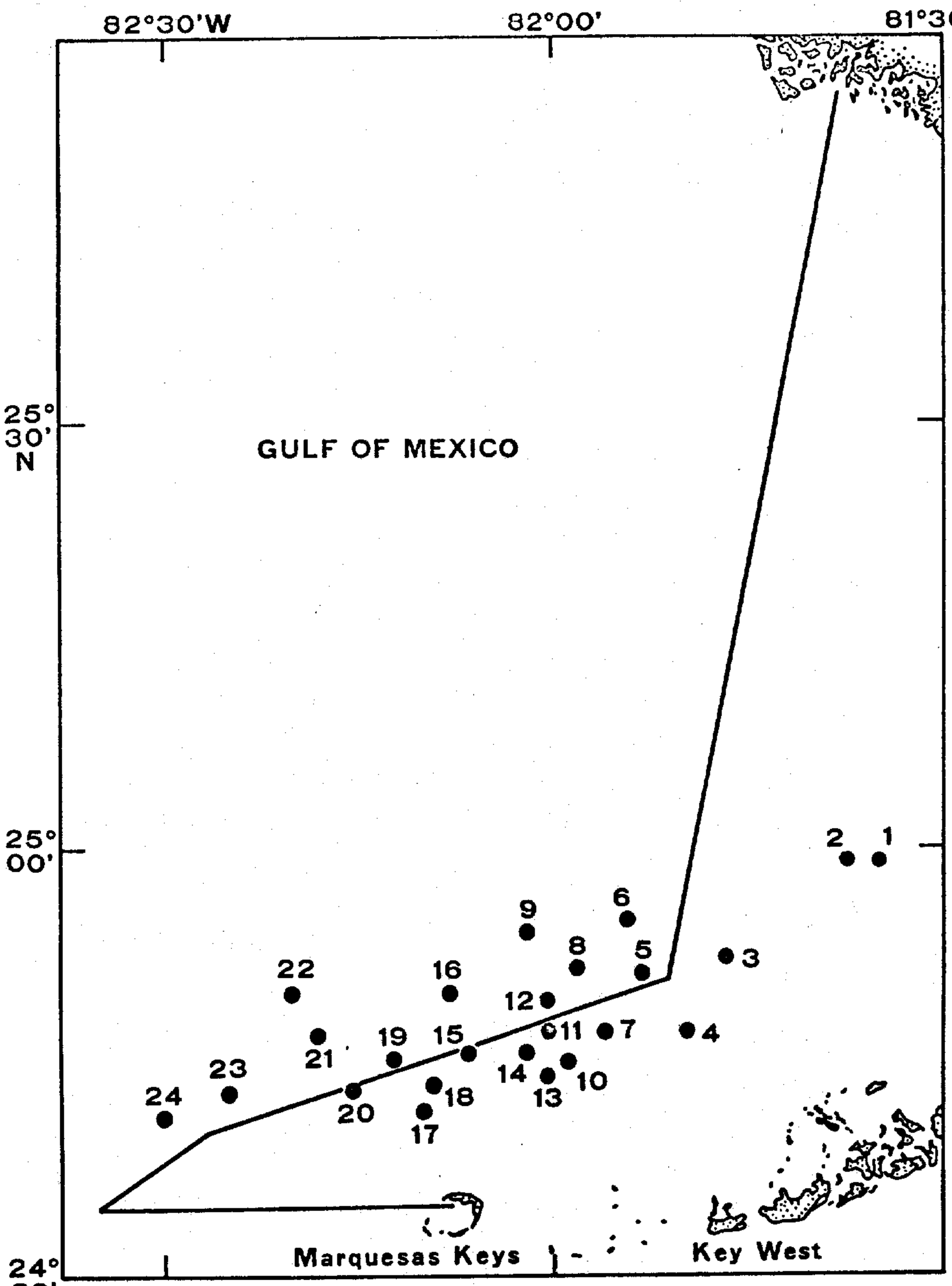

Figure 2. Map of the Tortugas Shrimp Sanctuary showing the location of 24 stations designated for monthly sampling.

12.2 m (40 ft) 4-seam flat trawls, tickler chains, and 2.4 m x 1.0 m (8 ft x 40 in) wooden doors, sampled each station at night once a month. The path of each 30 minute tow crossed at some point the station coordinates given in Table 1. Each station's towing path and location were recorded on a Loran C plotter, which has an accuracy in this region of about ± 125 ft, so that each month's sampling had a high probablity of covering the same towing path.

For the sake of convenience in handling large sample volumes brought in by four nets, it was decided to treat the data from the inboard nets differently from the outboard nets. All shrimp were sorted from the catch of all four nets separately, but only the total shrimp weight was recorded from both outboard nets. Data recorded from each inboard net included total catch weight, total fish weight, total shrimp weight, miscellaneous weight (invertebrates), and total number of shrimp (extrapolated from a three pound count of pink shrimp). In addition, a random sample of 200 pink shrimp was taken from the port inboard net for sex ratio determination and weights, total length measurements, and ovarian development determination. A five pound sample of shrimp was removed from the starboard inboard net and frozen for return to the Galveston Laboratory where total lengths and weights were determined along with a more exacting species composition. Thus, two replicate measures of shrimp weights and lengths were determined for each station.

Two hydrographic parameters, salinity and temperature, were recorded at each station at the surface and near the bottom. An optical refractometer with an accuracy of ± 0.5 o/oo and a mercury thermometer with an accuracy of ± 0.1°C were used to record the parameters.

Each monthly collecting trip was scheduled for seven nights. If any time remained after sampling each station, the captain was permitted to trawl within the sanctuary boundaries at his discre-

Table 1. Tortugas Shrimp Sanctuary station locations and depths.

Station	Latitude (° ')	Longitude (° ')	Depth (fm)
F1	24 59	81 35	6
F2	24 59	81 37	6
F3	24 52	81 46	8
F4	24 47	81 49	9
F5	24 51	81 53	9
F6	24 55	81 54	9
F7	24 47	81 56	9
F8	24 52	81 58	10
F9	24 54	82 02	12
F10	24 45	81 59	9
F11	24 47	82 00	10
F12	24 49	82 00	10
F13	24 44	82 00	9
F14	24 46	82 02	10
F15	24 45	82 07	11
F16	24 50	82 08	13
F17	24 41	82 10	8
F18	24 43	82 10	10
F19	24 45	82 12	11
F20	24 43	82 15	11
F21	24 43	82 19	11
F22	24 50	82 20	14
F23	24 43	82 25	11
F24	24 41	82 30	12

tion. Each commercial tow was timed, position coordinates recorded, and total shrimp weight estimated from the packaged catch. In addition, a randomly selected sample of 200 pink shrimp was sexed, measured, and weighed. A five pound box was collected at random from a maximum of six commercial tows during the cruise. These samples were frozen and returned to the Galveston Laboratory for processing.

All data derived from the Tortugas Shrimp Sanctuary collections were stored on magnetic tape files at the U.S. Office of Personnel Management Computer Service Center in Macon, Georgia. A Honeywell 66/80 computer in Macon and NMFS computer programs were used for some analysis of the data. A Tektronix 4051 mini-computer and 4662 plotter at the Galveston Laboratory were used for all analysis of variance, graphical analyses, and plotting.

RESULTS AND DISCUSSION

The analyses of data on length/frequency distribution of pink shrimp, catch effort, ovarian development, and hydrographic parameters for the six month period under consideration will be presented in this section of the report. The primary focus of this study is to examine the size distribution of pink shrimp so that the boundaries of the Tortugas Shrimp Sanctuary can be determined more precisely to protect immature shrimp without hindering the commercial harvest of larger shrimp. Therefore, the length/frequency distribution of these shrimp will be considered first.

LENGTH/FREQUENCY

Because these data consist of shrimp measurements taken at 24 stations over a six month period, data analysis must first determine if there are significant differences in shrimp lengths, not

only between stations (spatial distribution), but also between cruises (temporal distribution) as well as any interaction (spatial vs. temporal) between stations and cruises. Since the stations and cruises represent fixed treatment effects, a Model I two-way anova was used to test for any significance between these treatments and interaction as well (Sokal and Rohlf, 1969).

Two-Way Anlaysis of Variance

Table 2 shows the two-way anova for 23 stations x 6 cruises. Station F1 has been eliminated from all analyses because it could not be sampled on three of the six cruises due to the large number of crab traps spread randomly throughout the area. Samples from Stations F21 and F22 of Cruise IV (December 1981) could not be obtained due to the large amount of jellyfish (Aurelia sp.) brought up in the nets, and only one length/frequency sample was recovered at Stations F3 and F20 of Cruise I (September 1981). These missing values were replaced for computation of the two-way anova by estimates calculated using Yates' method (Steel and Torrie, 1960). These estimated values do not add information to the anova, therefore one degree of freedom should be subtracted from the error d.f and total d.f. for each estimated value. However, because only six d.f. are involved out of 138 error d.f. and 275 total d.f. and the computer program available on the Tektronix mini-computer does not allow for internal correction, this small adjustment was not made and, in this case, would not change the final results of the anlaysis.

Only the mean lengths from the two measured samples from each station were used in this analysis because of the prohibitive cost of computer time and memory had the complete data matrix of up to 400 or more shrimp lengths per station been used. Transformation of the mean values was not necessary since most of the values were

Table 2. Results of a two-way analysis of variance of shrimp mean lengths at 23 stations on six cruises. Station F1 has been deleted and missing values calculated for F3 and F20 of Cruise I and F21 and F22 of Cruise IV.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Cruises	5	2531.78	506.36	67.97	0.000***
Stations	22	2830.75	128.67	17.27	0.000***
Interaction	110	10637.38	96.70	12.98	0.000***
Error	138	1028.00	7.45		
Total	275	17027.91			

based on large numbers (>100) of measurements, which according to the Central Limit Theorem implies that the mean lengths should approach a normal distribution (a primary prerequisite for analysis of variance).

The shrimp length/frequencies from the two inboard nets have been pooled for each station except F1 of each cruise. Because there are 136 such histograms (there are no data for F21 and F22 of Cruise IV), they have not been included in this report, but will be furnished to interested parties upon request.

The two-way anova (Table 2) shows that not only are there significant differences between cruises ($P<.001$) and between stations ($P<.001$), but also in the interaction between cruises and stations ($P<.001$). This significant interaction means that when cruises and stations are considered together, the effect of either treatment (cruise or station) on size of shrimp cannot be predicted from the average response of the separate factors. Therefore, all further analyses will consist of one-way anova of the stations of each cruise considered separately. This method of analysis will exclude any added interaction effects and will allow a more meaningful interpretation of differences between stations of mean pink shrimp lengths.

Before leaving the two-way anova, it would be helpful to see the effects of interaction by examining Figure 3, a two-way plot of the mean lengths of 23 stations x 6 cruises. Each rectangle represents the relative size of the shrimp, i.e. the larger the rectangle, the greater the mean length of shrimp for that station and cruise. Cruises I and II show a general trend with the largest shrimp occurring at the western-most stations and the smallest near the eastern end. Cruises III and IV, however, show no clear segregation of size by station. Cruise III has very few large shrimp and they appear to be scattered in the middle and western stations.

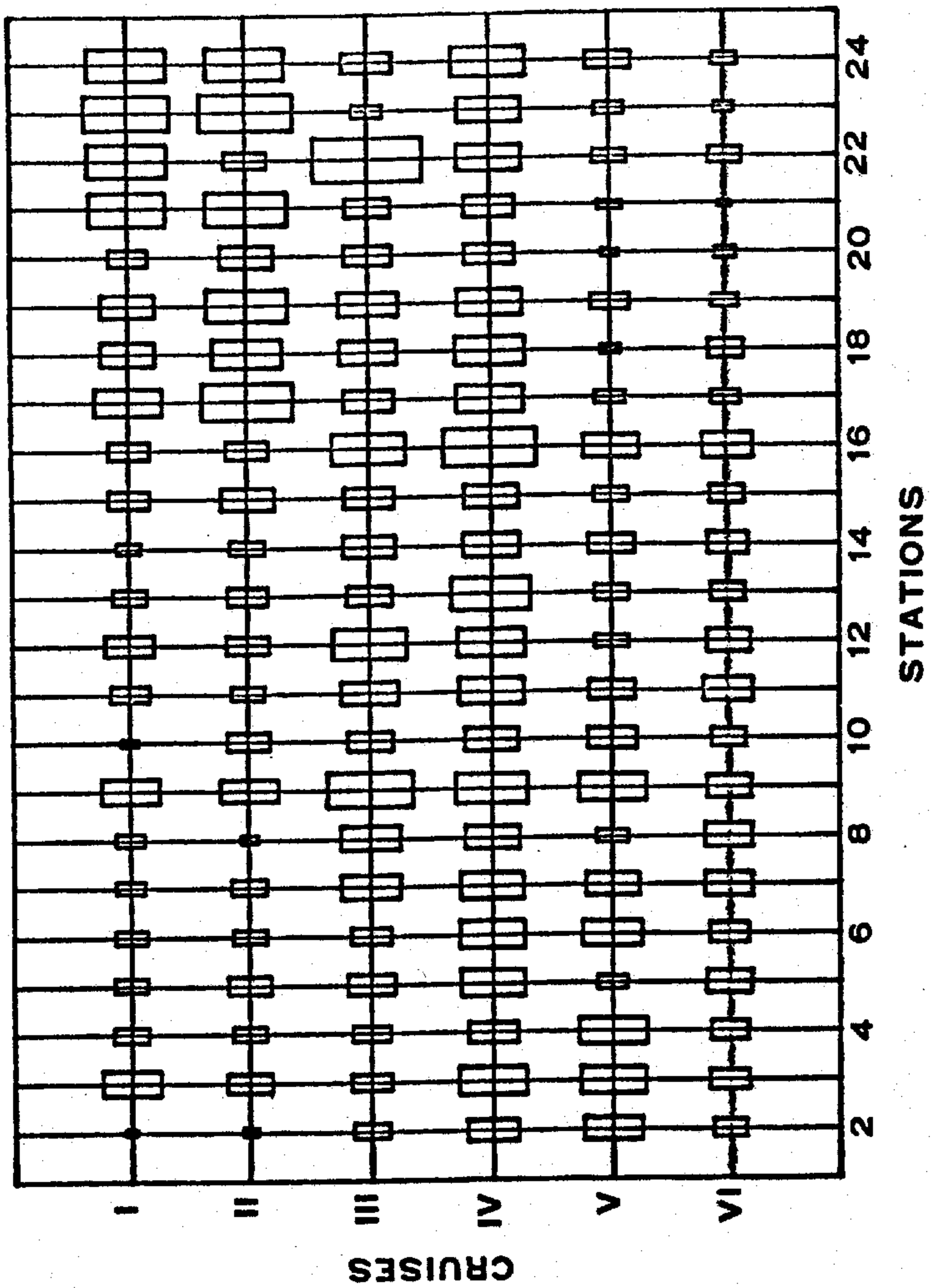

Figure 3. Two-way plot of shrimp mean lengths for 23 stations and six cruises. Each rectangle represents the relative mean length of pink shrimp at a station. Station F1 has been deleted.

Cruise IV shows an almost uniform distribution of large shrimp throughout the study area. Cruises V and VI, however, show a reversal of the size trends of Cruises I and II. Not only are the shrimp apparently smaller, overall, than on previous cruises, but the larger ones are located mostly at the shallower eastern end of the study area. These six cruises show a rather complex pattern of length/frequency distributions that is not easily interpreted. Because of this, the establishment of a pattern of movement or migration of pink shrimp cannot be described with any confidence at this early stage of the analysis.

One-Way Analysis of Variance

Table 3 shows the results of a one-way anova of each of the six cruises. In every case, there is a significant difference ($P<.001$) in the mean lengths of shrimp between the stations. In order to determine which stations caused the rejection of the null hypothesis of no difference in mean lengths, Student-Neuman-Keuls (S-N-K) stepwise multiple range test was employed (Sokal and Rohlf, 1969). This method arranges the means by ascending or descending order and then tests the range between largest and smallest means, then largest and next smallest mean, and continues in a step-wise fashion until a set of means is found that is not significantly different. One difficulty with this method is that when a large set of values are compared, several ranges may occur that will have several values in common. In such an event, one must then determine which arrangement gives the most meaningful biological interpretation of the results. In the final arrangement, it is sometimes necessary to reallocate one or more stations to a non-overlapping range which has similar mean values, but different variances. This is done to reduce the complexity of the data to a more comprehensible level. Examples of this action follow in the

Table 3. Results of a one-way analysis of variance of shrimp mean lengths between 23 stations of a cruise. Station F1 has been eliminated from all cruises. Stations F3 and F20 have been deleted from Cruise I and F21 and F22 from Cruise IV.

Cruise I

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	20	3446.00	172.30	30.66	0.000***
Error	21	118.00	5.62		
Total	41	3564.00			

Cruise II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	22	3787.83	172.17	37.36	0.000***
Error	23	106.00	4.61		
Total	45	3893.83			

Cruise III

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	22	2410.43	109.57	24.71	0.000***
Error	23	102.00	4.43		
Total	45	2512.43			

Table 3 (Continued)

Cruise IV

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	20	789.29	39.46	9.69	0.000***
Error	21	85.50	4.07		
Total	41	874.79			

Cruise V

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	22	1760.43	80.02	12.44	0.000***
Error	23	148.00	6.43		
Total	45	1908.43			

Cruise VI

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	22	1139.74	51.81	7.66	0.000***
Error	23	155.50	6.76		
Total	45	1295.24			

cruise analysis.

Table 4 is provided to allow quick translation of total length given in the following discussions to count size if needed.

Cruise I (September 17-23, 1981). Table 5 shows the results of the S-N-K test for 21 stations sampled during Cruise I (Station F1 has been excluded from all analyses as explained earlier and Stations F3 and F20 were excluded because they have only one sample mean each). Although there are several stations located in more than one range, careful examination suggests the existence of four major groups which are shown topographically in Figure 4. Only Station F17 had to be moved from one overlapping group to one of the four major groups. These groups show a general trend of increasing mean length of pink shrimp from eastern to western stations and agree fairly well with the two-way plot of mean lengths for Cruise I in Figure 3. In this case, the sanctuary boundaries do protect some of the small shrimp, but these same immature shrimp can also be found outside the line. Only Stations F17 and F18 inside the sanctuary have shrimp whose mean length exceeds the Florida legal minimum size of 103 mm.

Cruise II (October 21-28, 1981). The results of the S-N-K test for 23 stations sampled in October 1981 are shown in Table 6. Seven ranges or groups were identified in this data set, but they were reduced again to only four major groups. Stations F18 and F23 were reallocated from separate groups and placed in Group D (see Table 6 and Fig. 5). Stations F3, F5, F10, F12, F13, F16, and F22 occurred in both Groups B and C. Inspection of the station mean lengths revealed they had a greater similarity to the other mean lengths in Group B and were therefore removed from Group C. The results of this analysis are portrayed topographically in Figure 5. The same

Table 4. Conversion values for translating total shrimp length (mm) into shrimp counts (heads-on/lb and heads-off/lb) for pink shrimp. The values given are for combined counts (average of male-female counts).

Total Length (mm)	Number Per Pound Heads-on	Heads-off	Total Lengths (mm)	Number Per Pound Heads-on	Heads-off
90	70.9	112.0	112	36.5	58.6
91	68.3	108.1	113	35.5	57.1
92	66.0	105.6	114	34.6	55.4
93	64.4	100.9	115	33.7	54.1
94	61.8	97.6	116	32.8	52.5
95	60.1	95.5	117	32.0	51.4
96	58.2	92.6	118	31.1	49.9
97	56.4	89.0	119	30.4	48.8
98	54.7	87.3	120	29.6	47.6
99	52.8	84.1	121	28.8	46.3
100	51.3	81.8	122	28.2	45.4
101	49.9	79.6	123	27.5	44.1
102	48.5	77.6	124	26.8	43.3
103	47.0	75.0	125	26.2	42.1
104	45.7	72.7	126	25.5	41.1
105	44.3	70.4	127	24.9	40.0
106	43.3	68.8	128	24.4	39.4
107	41.9	66.8	129	23.8	38.4
108	40.7	64.9	130	23.2	37.4
109	39.7	63.5	131	22.7	36.5
110	38.5	61.8	132	22.2	35.7
111	37.6	60.2	133	21.7	34.9

Table 5. Results of a Student-Neuman-Keuls range test on shrimp mean lengths at 21 stations of Cruise I. Stations F1, F3, and F20 have been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Lengths (mm)	Nonsignificant Ranges Used
	2	90.0	A
	10	92.0	
	14	95.5	
	7	97.5	B
	8	97.5	
	6	99.0	
	5	99.5	
	13	100.0	
	4	100.5	
	11	102.0	
	15	103.0	
	16	103.0	
	12	106.0	C
	19	108.0	
	18	108.5	
	9	110.5	
	17	114.0	D
	21	118.0	
	24	119.0	
	22	119.5	
	23	122.0	

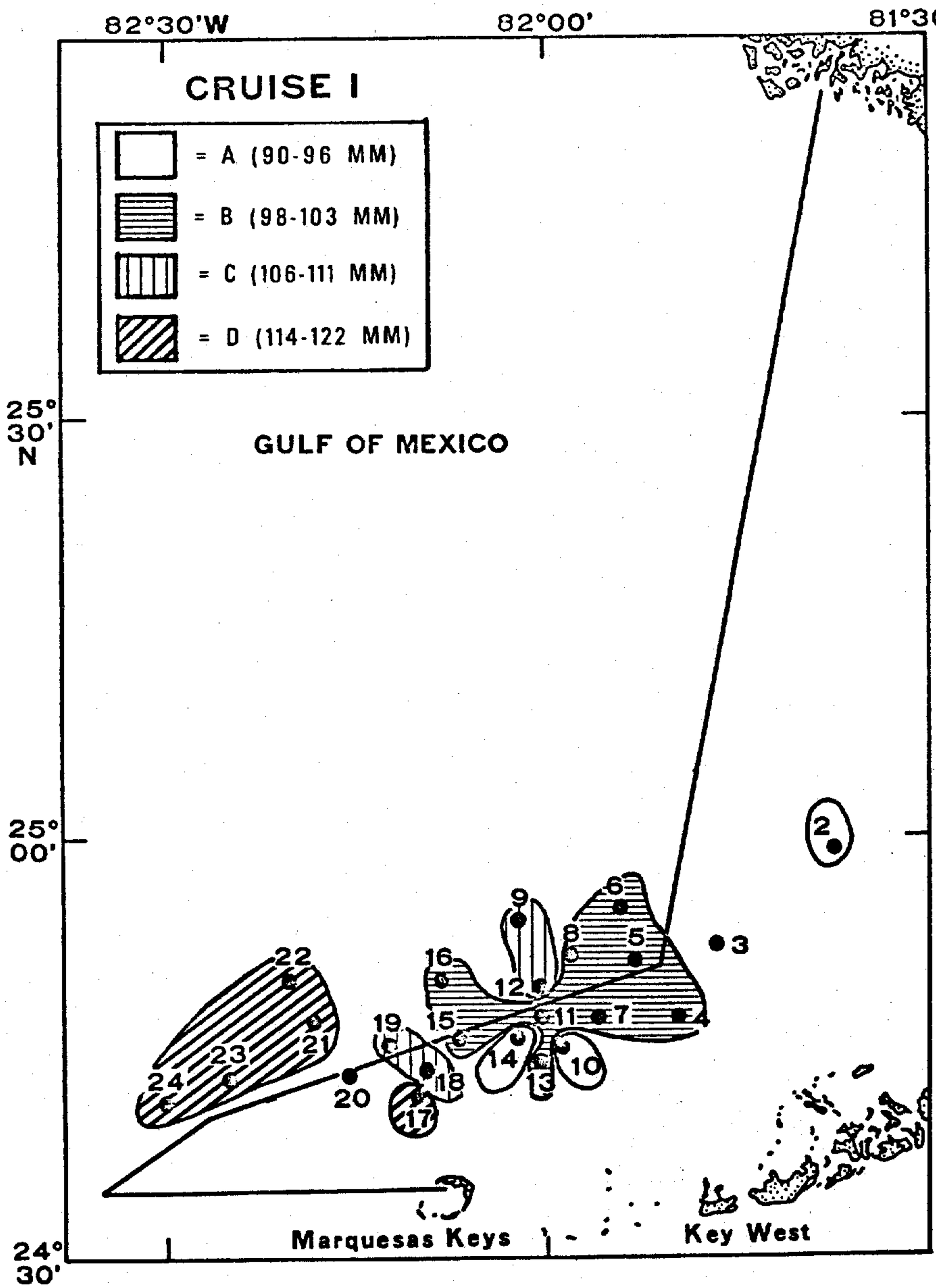

Figure 4. Sample stations grouped by the Student-Neuman-Keuls test according to the mean lenghts of pink shrimp occurring at each site of Cruise I (September 1981). Stations F1, F3 and F20 have been deleted.

Table 6. Results of a Student-Neuman-Keuls range test on shrimp mean lengths at 23 stations of Cruise II. Station F1 has been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Lengths (mm)	Nonsignificant Ranges Used
	2	91.5	A
	8	92.5	
	4	99.0	B
	11	99.0	
	6	99.5	
	7	100.0	
	14	100.0	
	13	102.0	
	5	102.5	
	10	102.5	
	12	102.5	
	22	102.5	
	16	103.0	
	3	104.0	
	15	107.5	C
	20	107.5	
	9	109.0	
	18	114.5	D
	24	118.0	
	19	119.0	
	21	119.5	
	17	123.0	
	23	124.5	

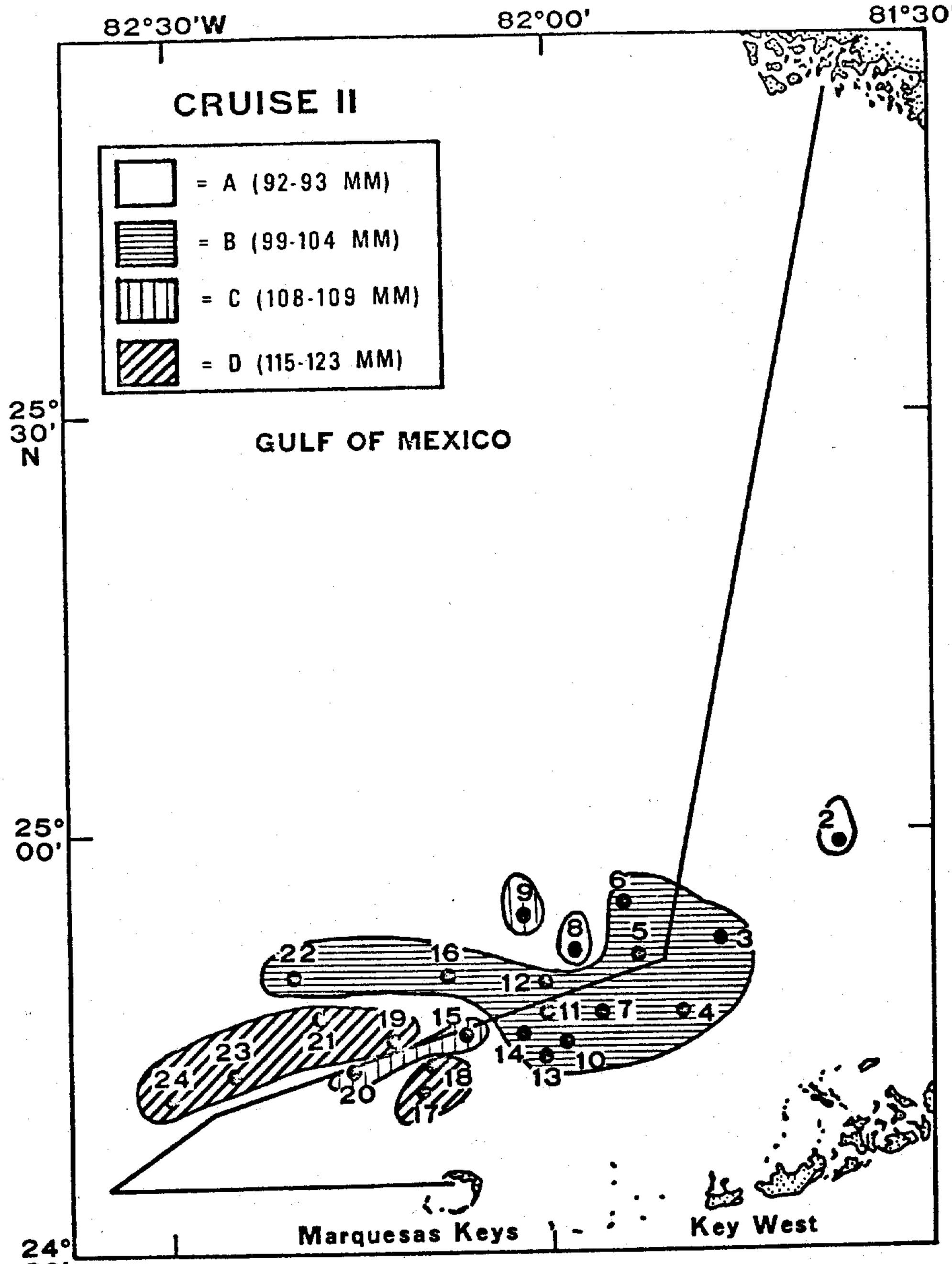

Figure 5. Sample stations grouped by the Student-Neuman-Keuls test according to the mean lengths of pink shrimp occurring at each site of Cruise II (October 1981). Station F1 has been deleted.

general trends that occurred during September can be found in the October data. There is a general increase in mean length toward the western stations. However, since both sizes can be found on either side of the line, the sanctuary boundary does not reflect the overall distribution of small or large pink shrimp.

Cruise III (November 16-23, 1981). The size distribution of shrimp in November 1981 represents a change from the trend developed in the first two crusies. Once again there are four major groups of stations delineated by the S-N-K test (Table 7), but three stations (F6, F11, F23) must be reallocated from separate overlapping groups and placed in the major groups. In addition, one station (F22) was significantly different from all the groups and remains by itself. The results are shown topographically in Figure 6. Size distributions are more complicated in November, but with the exception of Station F23, the smallest shrimp (<103 mm) are found at the eastern stations (F2, F3, F4, F6). The largest shrimp are found at Stations F9, F12, F16, and F22 in the middle of the east-west line of sampling sites and outside the sanctuary boundary. Except for Stations F6 and F23, the sanctuary provides protection for shrimp under 103 mm total length. However, mid-sized shrimp (104-110 mm) are also found inside the sanctuary boundary.

Cruise IV (December 9-16, 1981). With all stations and months considered during this study, the largest shrimp overall were caught in December 1981. No station had a mean size less than 106 mm total length, indicating a general decrease in numbers of undersized shrimp in the study area. Table 8 shows that only two major groups are needed to cluster the stations in the S-N-K test, and that Station F16 is significantly different and does not cluster with the other stations. Stations F21 and F22 could not be sampled

Table 7. Results of a Student-Neuman-Keuls range test on shrimp mean lengths at 23 stations of Cruise III. Station F1 has been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Lengths (mm)	Nonsignificant Ranges Used
	23	97.5	A
	2	100.0	
	4	100.5	
	3	101.5	
	6	102.0	
	10	103.5	B
	13	103.5	
	21	103.5	
	5	105.0	
	20	105.0	
	15	106.0	
	17	106.0	
	24	106.0	
	14	107.0	
	11	108.5	C
	18	109.0	
	8	109.5	
	19	109.5	
	7	110.0	
	12	115.5	D
	16	115.5	
	9	120.5	
	22	131.0	E

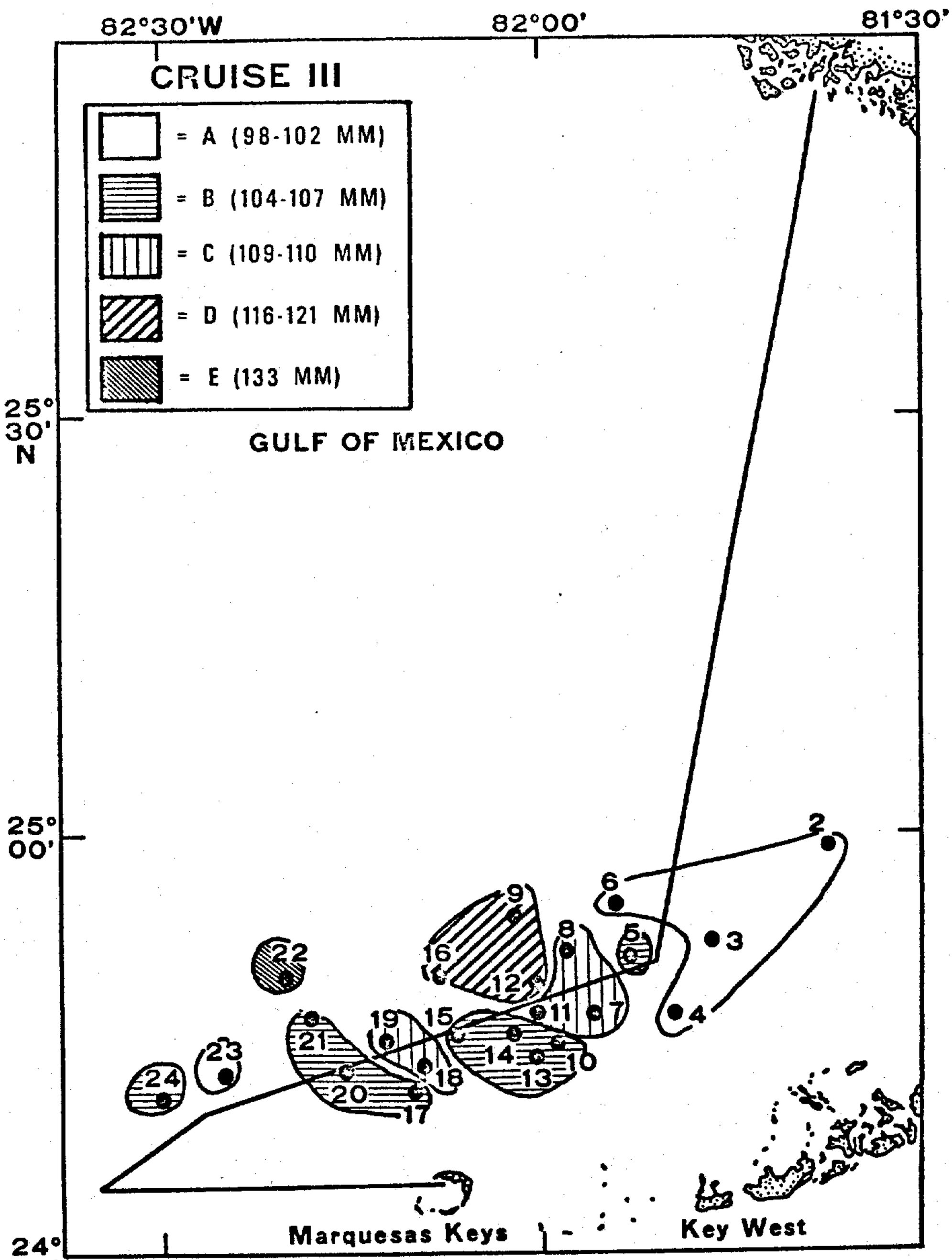

Figure 6. Sample stations grouped by the Student-Neuman-Keuls test according to the mean lengths of pink shrimp occurring at each site of Course III (November 1981). Station F been deleted.

Table 8. Results of a Student-Neuman-Keuls range test on shrimp mean lengths at 21 stations of Cruise IV. Stations F1, F21, and F22 have been deleted. Letters below non-significant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Lengths (mm)	Nonsignificant Ranges Used
	4	106.0	A
	2	106.5	
	20	106.5	
	10	107.5	
	8	108.0	
	15	108.0	
	14	109.0	
	7	111.0	B
	5	111.5	
	23	111.5	
	11	112.0	
	19	112.0	
	6	112.5	
	3	113.0	
	17	113.0	
	12	113.5	
	18	114.5	
	9	115.5	
	24	116.5	
	13	118.0	
	16	124.5	C

at this time. The topographic distribution shown in Figure 7 is complicated, but in general, the smallest shrimp, although larger than the Florida count law, are found inside the sanctuary. Based on December's data, the need for a sanctuary during December does not appear to be as great as in the three previous months.

Cruise V (January 19-26, 1982). The size trends in January 1982 are somewhat easier to interpret than in the previous two months. Table 9 shows three major groups in the size data, and Figure 8 again reveals a general east-west trend in size. However, this trend is the reverse of that found in September and October 1981. The largest mean sizes are found at the eastern stations, both inside and outside the sanctuary, and the smallest sizes are generally at the western end. Most of the stations where small shrimp were found are outside the limits of the sanctuary; therefore, small shrimp are afforded no protection.

Cruise VI (February 18-24, 1982). The size distribution of shrimp in samples obtained during this cruise is more complex than Cruise V, but there is some overall similarity between the two. Table 10 shows three major groups of mean lengths with the smallest shrimp occurring once again at the western-most stations and mostly outside the sanctuary (Fig. 9). However, the largest shrimp (108-111 mm) are now located in a group of stations in the middle of the study area and only Stations F7 and F11 of this group are inside the sanctuary. The mid-sized shrimp (102-106 mm) are primarily inside the sanctuary and located at the middle and eastern stations.

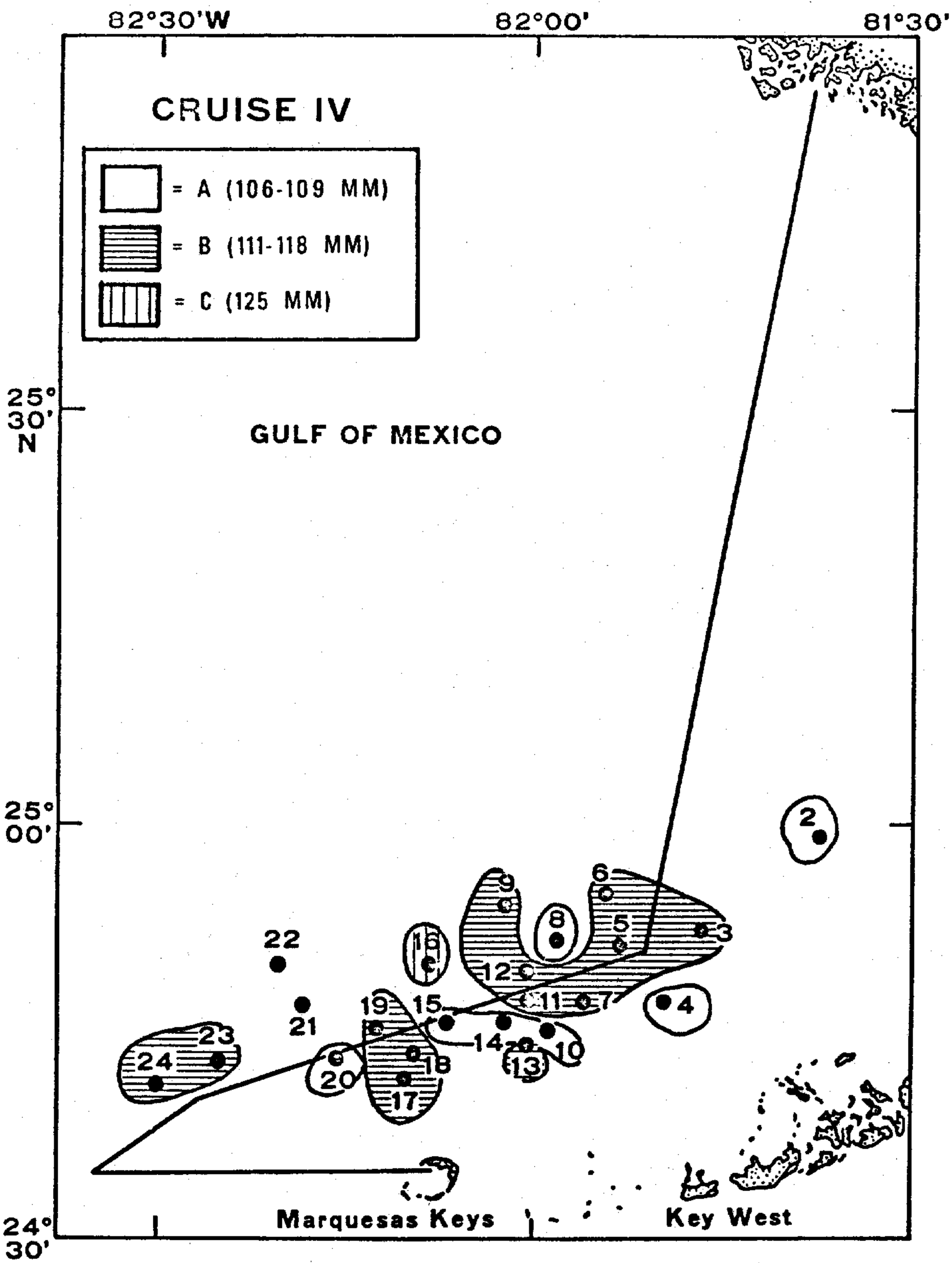

Figure 7. Sample stations grouped by the Student-Neuman-Keuls test according to the mean lengths of pink shrimp occurring at each site of Cruise IV (December 1981). Stations F1, F21 and F22 have been deleted.

Table 9. Results of a Student-Neuman-Keuls range test on shrimp mean lengths at 23 stations of Cruise V. Station F1 has been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Lengths (mm)	Nonsignificant Ranges Used
	20	92.5	A
	18	93.5	
	21	95.0	
	23	97.0	
	5	97.5	
	17	97.5	
	8	98.0	
	12	99.0	
	15	99.0	
	22	99.0	
	13	99.5	
	19	101.5	B
	24	104.0	
	11	104.5	
	14	104.5	
	10	105.5	
	7	107.5	
	16	108.5	C
	2	109.0	
	6	110.0	
	3	112.0	
	4	113.0	
	9	113.0	

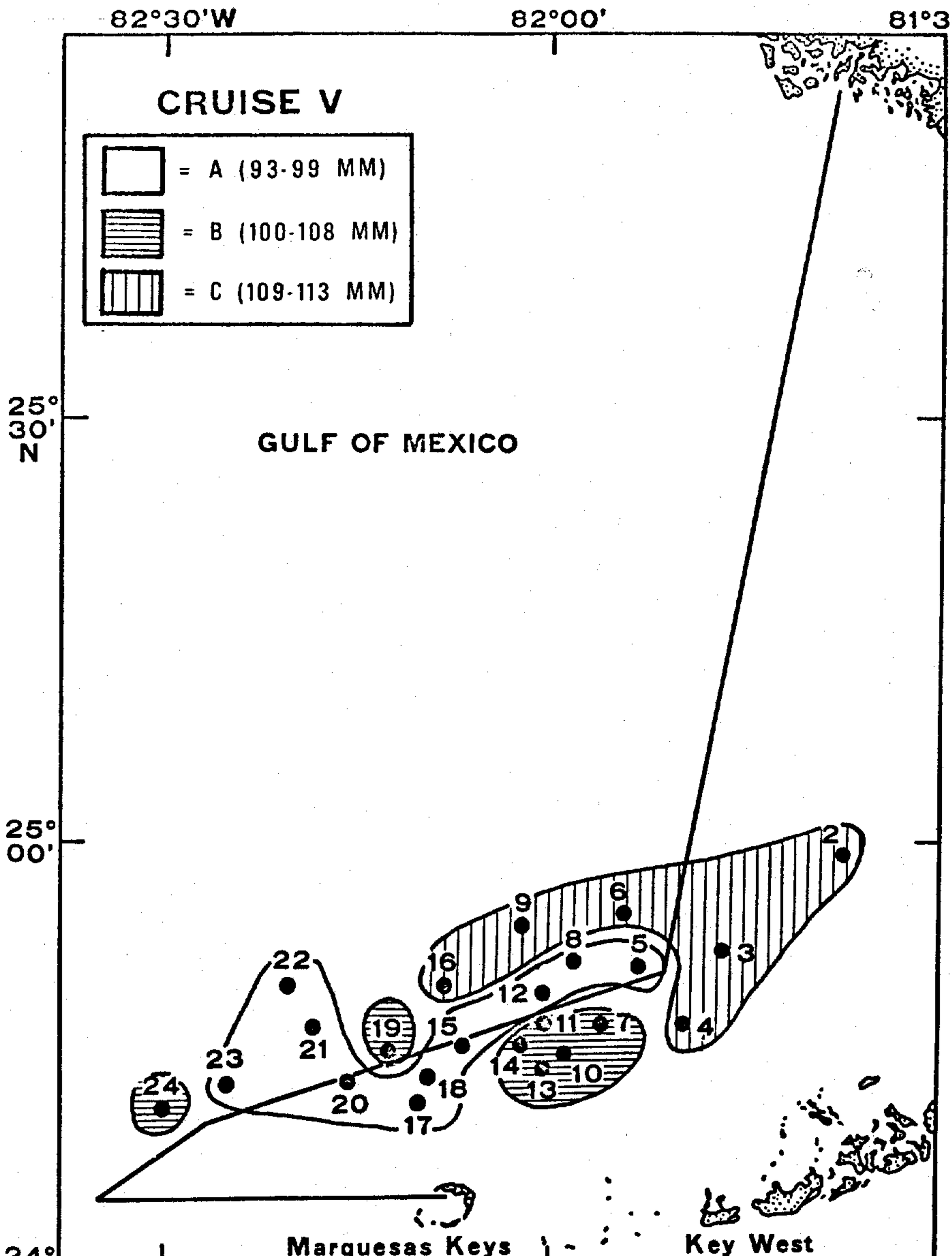

Figure 8. Sample stations grouped by the Student-Neuman-Keuls test according to the mean lengths of pink shrimp occurring at each site of Cruise V (January 1982). Station F1 has been deleted.

Table 10. Results of a Student-Neuman-Keuls range test on shrimp mean lengths at 23 stations of Cruise VI. Station F1 has been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Lengths (mm)	Nonsignificant Ranges Used
	21	91.5	
	23	95.0	
	20	96.0	A
	24	97.5	
	19	98.5	
	17	99.5	
	22	101.5	
	2	102.0	
	10	102.5	
	13	102.5	
	15	103.0	
	18	103.0	B
	4	104.0	
	3	104.5	
	6	105.0	
	14	106.0	
	9	107.5	
	12	107.5	
	5	108.0	
	7	109.0	C
	8	109.0	
	11	110.0	
	16	110.5	

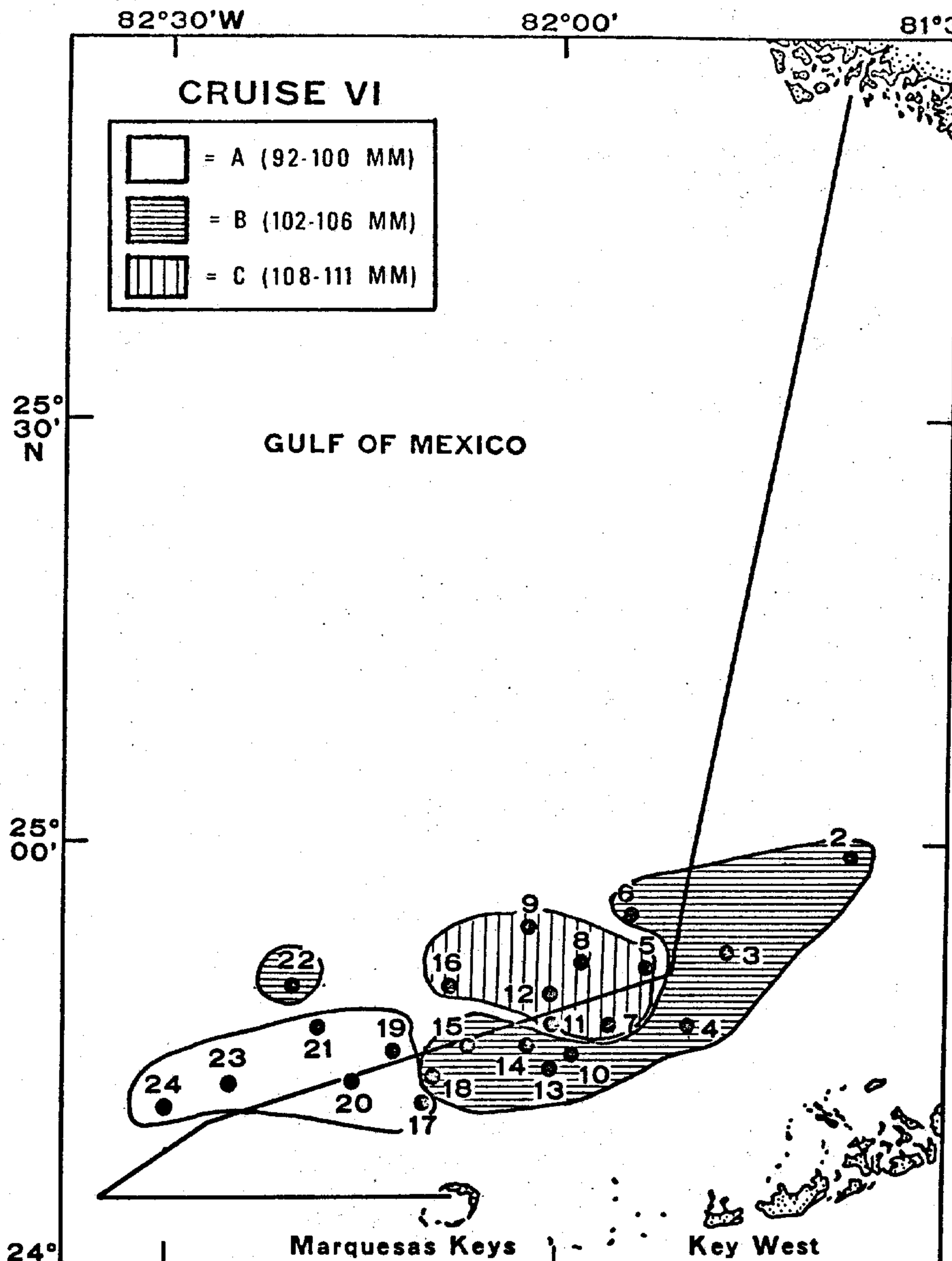

Figure 9. Sample stations grouped by the Student-Neuman-Keuls according to the mean lengths of pink shrimp occurri at each site of Cruise VI (February 1982). Station has been deleted.

Discussion

In a discussion of size distribution of shrimp, the terms "small" and "large" are relative and carry different meanings to different readers. In an effort to define and divide these two size categories, an arbitrary size of 103 mm total length (equivalent to a count of 47 heads-on/lb) was chosen based on the Florida count law as previously described. Thus, small shrimp refer to those pink shrimp less than 103 mm total length and large shrimp are those greater than 103 mm total length.

Although no simple pattern in the mean size distribution of pink shrimp has emerged in the first six month's data, the data indicate that the largest shrimp are found at the western end of the study area during September and October 1981 and the smallest shrimp are at the eastern end. This pattern shifts in November 1981 with the largest shrimp now being found in the middle of the study area, but the smallest shrimp are still at the shallower eastern end. Therefore, for the first three months (September through November), the sanctuary provides protection for most of the small shrimp at the eastern end, but also includes large shrimp inside the exclusion zone in the middle and western regions.

December 1981 data are unique in this study in that small shrimp, although present, appear to represent a smaller fraction of the biomass of the population since the mean lengths of shrimp at all stations are 106 mm or greater. Based on the mean lengths of shrimp taken during this month, it appears that the need for protection of small shrimp is not as great as in the three previous months. In fact, the sanctuary line may only prevent the harvest of larger shrimp.

January and February 1982 data represent another shift in the size distribution pattern. The January pattern is more complex

than February's, but in general, the smallest shrimp are now located in the deeper western stations of the study area, both inside and outside the sactuary, and the largest shrimp are found near the middle and eastern end. Thus, both small and large shrimp can be found inside and outside the sanctuary in each month of this study. This points out the fact that the line is not always protecting all of the small shrimp and during certain months, may only prevent the commercial harvest of large shrimp at certain sites (e.g. December). This distribution pattern makes it difficult to envision a sanctuary that would protect the small shrimp, yet allow the harvest of large shrimp at the same time.

Since it is difficult to describe a detailed distribution pattern for pink shrimp in these data based on station or monthly differences, Tables 11, 12 and 13 were prepared to simplify the analysis by consolidating stations inside or outside the sanctuary. This approach will present a broad overview of shrimp distribution in and around the sanctuary, but it will also mask small scale spatial differences (station to station) that also appear in the data as presented in the above discussion.

Table 11 shows the relative abundance of pink shrimp inside and outside the sanctuary based on the total population of shrimp taken at all stations for each month. The percentages of shrimp $<$103 mm or $\geq$103 mm were calculated from the total number caught at each station (extrapolated from the 3 lb. count). Then, by using the length/frequency determinations for each station, the number of shrimp in each size category was determined. These numbers were summed for the stations inside the line and again for the stations outside the line and then divided by the overall total number of shrimp in order to derive the percentages in Table 11. Stations F1 and F2 were deleted: F2 was deleted in order to get an even number

Table 11. The monthly relative abundance of pink shrimp found inside and outside the sanctuary based on the total popu-laton taken at all sampling stations combined (except for Stations F1 and F2). The shrimp are divided according to total length <103 mm and ≥103 mm.

	Inside Sanctuary		Outside Sanctuary	
	% <103 mm	% ≥103 mm	% <103 mm	% ≥103 mm
September	48	23	11	18
October	32	33	12	23
November	36	37	12	15
December	19	50	7	24
January	41	25	23	11
February	40	33	15	12

of stations on both sides of the sanctuary and F1 was deleted for reasons previously explained. Data were not taken for Stations F21 and F22 in December and had to be created by using an average value from all stations outside the sanctuary in December in order to minimize the bias in these calculations.

The total number of shrimp <103 mm and ≥103 mm for all stations by month used in Tables 11-13 are presented in the appendix.

When considering the distribution of the total population of shrimp, two trends become apparent in Table 11. First, most of the small shrimp (19%-48%) are found inside the sanctuary (a fact which is emphasized in Table 13) when compared to the percentage outside the line (7%-23%). Second, most of the large shrimp (23%-50%) occur inside the sanctuary with December having the highest percentage (50%). However, most of the shrimp outside the line are ≥103 mm (15%-24%), except for the months of January and February (11% and 12%, respectively). These last two months are unusual in that small shrimp (55%-64% <103 mm vs. 36%-45% ≥103 mm) dominate the population as a whole. December data are opposite to January and February data, however, in that large shrimp (74% ≥103 mm vs. 26% <103 mm) are dominant in the population. Thus, the sanctuary may not be needed in December (at least where the sampling stations are located).

Another way of looking at these data is to directly compare and contrast the populations inside and outside the sanctuary. Thus, Table 12 compares the percentages of small and large shrimp caught at stations inside the sanctuary to those caught outside the sanctuary. These percentages were calculated as explained for Table 11, except the total populations are derived from the combined stations inside the sanctuary or from the combined stations outside the sanctuary. As a result, for shrimp caught only inside the line, over half (50%-68%) of these shrimp are <103 mm for all

Table 12. The monthly relative abundance of pink shrimp <103 mm and ≥103 mm total length occurring at stations located inside the sanctuary and at stations outside the sanctuary, as well as all stations combined. Stations F1 and F2 have been excluded.

	Inside		Outside		Combined	
	<103 mm	≥103 mm	<103 mm	≥103 mm	<103 mm	≥103 mm
September	68	32	37	63	59	41
October	50	50	34	66	44	56
November	51	49	45	55	48	52
December	28	72	23	77	26	74
January	62	38	68	32	64	36
February	55	45	56	44	55	45

months except December (28%). Again, as shown in Table 11, the stations outside the line are dominated by large shrimp (55%-77%), except for January and February (32% and 41%, respectively).

In order to emphasize the distribution of small shrimp (i.e., whether they are mostly inside or outside the sanctuary), Table 13 was prepared by subdividing the total shrimp population into two populations according to total length <103 mm or ≥103 mm. The percentages of all shrimp <103 mm or ≥103 mm occurring inside the sanctuary for each month are shown in Table 13. This best illustrates the abundance and distribution of small shrimp, but, at the same time, may be misleading. As an example, Table 13 does show a large majority of the small shrimp population (63%-82%) is inside the sanctuary. However, it should be remembered that for December (72% in Table 13), small shrimp make up only 26% (Table 11) of the total population.

Thus, even though the sanctuary does appear to be protecting the majority of the small shrimp population (Table 13), this observation is based on a consolidation of all station data by month. As pointed out in the S-N-K analyses of mean lengths at the sampling sites, certain stations inside the sanctuary contain predominantly larger shrimp and their distribution is variable by month. Therefore, the generalized picture given in Tables 11, 12, and 13 does not show the complex nature of shrimp size distribution, but on the other hand, the overall view is more easily understood.

CATCH PER UNIT EFFORT

The catch per unit effort (CPUE) data consists of two parts: total shrimp weight per net at the 23 sampling stations and estimated total shrimp weight from all nets combined during the commercial tows. In order to standardize the catch effort, CPUE will be

Table 13. The monthly relative abundance of pink shrimp occurring inside the sanctuary. Percentages are based on the total population of shrimp <103 mm and the total population ≥103 mm at all sampling stations, except Stations F1 and F2.

	Inside Sanctuary	
	% of Total Population <103 mm	% of Total Population ≥103mm
September	82	56
October	73	59
November	75	71
December	72	67
January	63	70
February	72	73

defined as the weight of all shrimp (heads-on) in pounds per 40 foot net per 30 minute tow.

Since four nets were towed simultaneously, a one-way anova was used to check for any significant difference in the catch between any of the nets. A preliminary check on the data using Taylor's power law equation (Taylor, 1961) indicated the need for a square root transformation of the data before testing with analysis of variance. Table 14 shows the results of the anova of the transformed data. There was no statistical difference ($P = .827$) in shrimp weight between the nets and Bartlett's test indicated that all variances were homogeneous. Therefore, the mean weight of all nets was used for each station in the following analysis.

Table 15 shows the results of a one-way anova of CPUE for all stations of each cruise. The station CPUEs for each cruise are significantly different ($P<.001$), indicating a patchy distribution in shrimp abundance in the study area. The Student-Neuman-Keuls stepwise test was also applied to the transformed CPUE data of each cruise in order to identify which stations were significantly different. A complex pattern emerged as a result of this treatment of the data. In general, however, the highest CPUEs for all six cruises occurred inside the sanctuary. Data for each cruise are presented separately.

Cruise I (September 17-23, 1981)

Table 16 shows the results of the S-N-K test on the September 1981 data. There were seven groups identified by the test, but only four groups were necessary to cluster the stations (Fig. 10). Stations F10, F14, F2 (55.5, 40.5, and 0.2 lbs, respectively) were sufficiently different that thay did not cluster with any other group and remain separate. As stated above, the highest CPUEs (at Stations F10, F14, F4, F13, F17, and F18) occurred inside the sanctuary, but F21, also in the same group, is located outside the

Table 14. Results of a one-way analysis of variance of shrimp weight between four nets on five cruises. A square root transformation was used on the weights data. Cruise I was deleted because only two nets were sampled at each station. Station F1 was deleted from all cruises and Stations F2, F3, F12, F15, F17 of Cruise II; F2, F3 of Cruise III; F2, F21, F22 of Cruise IV; F2, F11 of Cruise V; and F2, F9 of Cruise VI were also deleted because samples were not collected from all four nets.

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Nets	3	1.91	0.64	0.298	0.827
Error	400	854.95	2.14		
Total	403	856.86			

Table 15. Results of one-way analyses of variance of shrimp weight between stations for six cruises. A square root transformation was used on the weights data. Stations F1, F2, F3 have been eliminated from all cruises and Stations F21 and F22 from Cruise IV.

Cruise I

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	20	81.36	4.07	29.39	0.000***
Error	21	2.91	0.14		
Total	41	84.27			

Cruise II

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	20	121.96	6.10	48.11	0.000***
Error	59	7.48	0.13		
Total	79	129.44			

Cruise III

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	20	167.95	8.40	202.29	0.000***
Error	63	2.62	0.04		
Total	83	170.57			

Table 15 (Continued)

Cruise IV

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	18	98.22	5.46	63.04	0.000***
Error	57	4.93	0.09		
Total	75	103.16			

Cruise V

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	20	187.31	9.37	75.31	0.000***
Error	62	7.71	0.12		
Total	82	195.02			

Cruise VI

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F	Significance Level (P=)
Stations	20	110.24	5.51	62.77	0.000***
Error	62	5.44	0.09		
Total	82	115.68			

Table 16. Results of a Student-Neuman-Keuls range test on shrimp weights at 21 stations of Cruise I. A square root transformation was used on weights data. Stations F1, F3, and F20 have been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Lengths ($\sqrt{lbs}$)	Nonsignificant Ranges Used
	2	0.38	A
	9	1.66	
	23	1.80	B
	22	2.34	
	12	2.64	
	8	2.65	C
	5	2.72	
	11	2.83	
	6	3.30	
	19	3.30	
	16	3.67	
	7	3.74	D
	24	3.74	
	15	4.06	
	21	4.36	
	18	4.42	
	13	4.60	E
	4	4.65	
	17	5.43	
	14	6.34	F
	10	7.45	

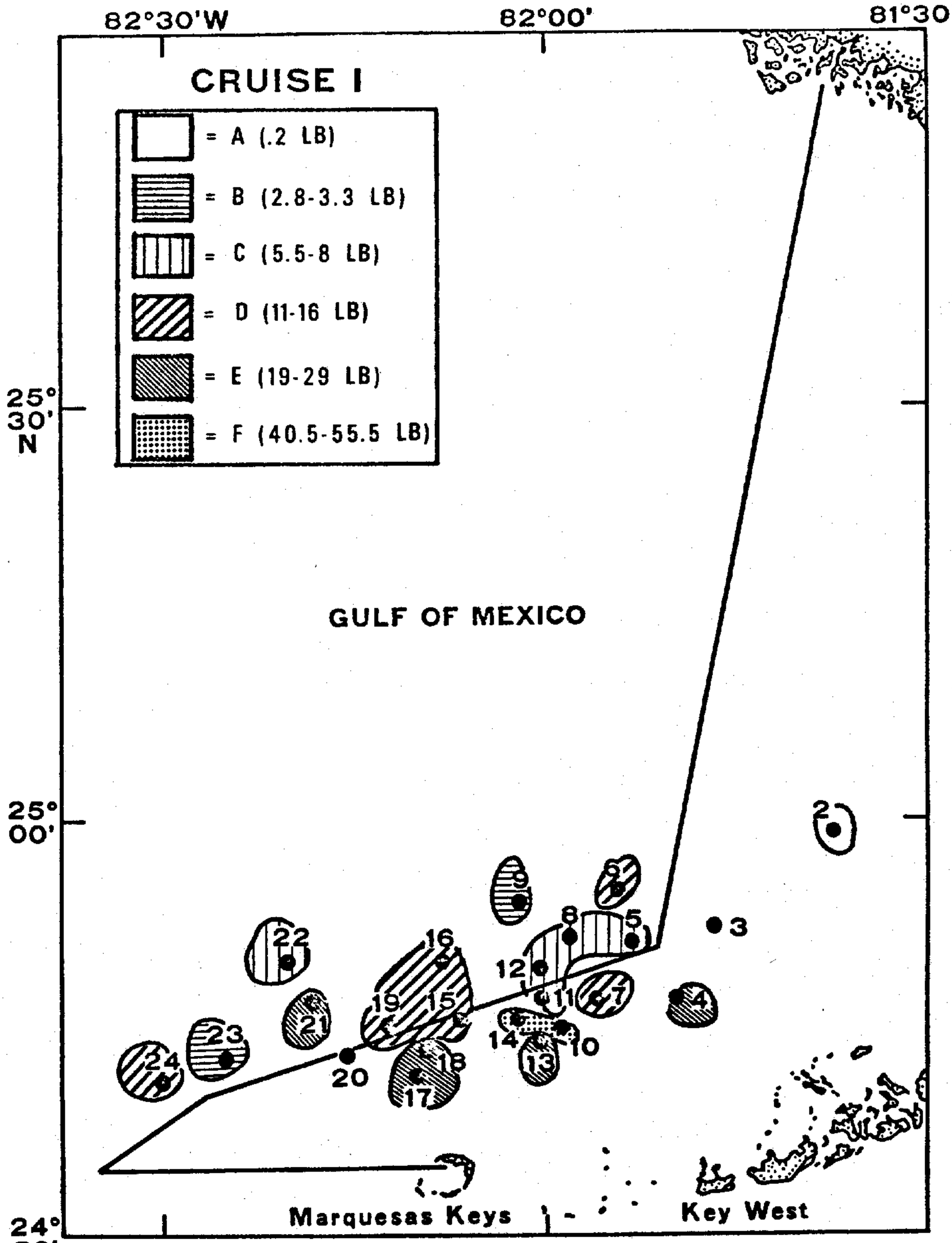

Figure 10. Sample stations grouped by the Student-Neuman-Keuls test according to mean shrimp weights occurring at each site of Cruise I (September 1981). Stations F1, F3 and F20 have been deleted.

line. The lowest CPUE (0.2 lbs) is found at Station F2 inside the sanctuary and Station F9 and F23 (2.8-3.3 lbs) outside the line. Although the highest CPUE occurred at Stations F10 and F14, these stations had the smallest (90-96 mm) shrimp (see Fig. 4). The largest shrimp at Stations F17 and F21 (114-122 mm) occurred in the next highest CPUE group (Group E in Fig. 10), otherwise, the larger shrimp did not always occur in large numbers during this cruise.

Cruise II (October 21-28, 1981)

Table 17 shows a complex arrangement of ten station groups for the October 1981 data, but they can be reduced to six major groups. With the exception of Station F16 which is outside the sanctuary, the results of this cruise were similar to that of Cruise I. The highest CPUE (17-25 lbs) (F13, F17, F10, F18, and F20) occurred inside the sanctuary (Fig. 11). However, other than the highest CPUEs occurring inside the line, there is no general recognizable trend in the data. Only Stations F17 and F18 have both a high CPUE and a large mean length (115-123 mm). Stations F19, F21, and F23 have a mean length of 115-123 mm, but a CPUE of only 10-13 lbs.

Cruise III (November 16-23, 1981)

The November data (Table 18) show nine groups plus three stations which did not join any other groups. Only four major groups and three stations (F4, F9, F10) are shown in Figure 12. Stations F4 and F10 are separate and have the highest CPUE (40.9-45.3 lbs), but the smallest (100.5-103.5 mm) shrimp (see Fig. 6). Station F9 was also separated and had the lowest CPUE (1.1 lbs) of all stations, but one of the largest mean lengths (120.5 mm)..

In general,this pattern of inverse relationship between shrimp size and CPUE follows for the other groups in Figure 12. Clusters in this cruise differ from September and October in that the CPUE groups are generally arranged in bands with decreasing CPUE with

Table 17. Results of a Student-Neuman-Keuls range test on shrimp weights at 23 stations of Cruise II. A square root transformation was used on weights data. Station F1 has been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Weigths ($\sqrt{lbs}$)	Nonsignificant Ranges Used
	8	0.62	A
	2	0.77	
	12	1.00	
	5	1.26	
	6	1.59	B
	3	1.69	
	24	1.71	
	4	1.80	
	22	2.09	C
	14	2.10	
	9	2.22	
	15	2.50	
	11	2.64	
	7	3.24	D
	23	3.32	
	21	3.56	
	19	3.60	
	20	4.10	E
	10	4.16	
	18	4.21	
	16	4.36	F
	17	4.65	
	13	4.94	

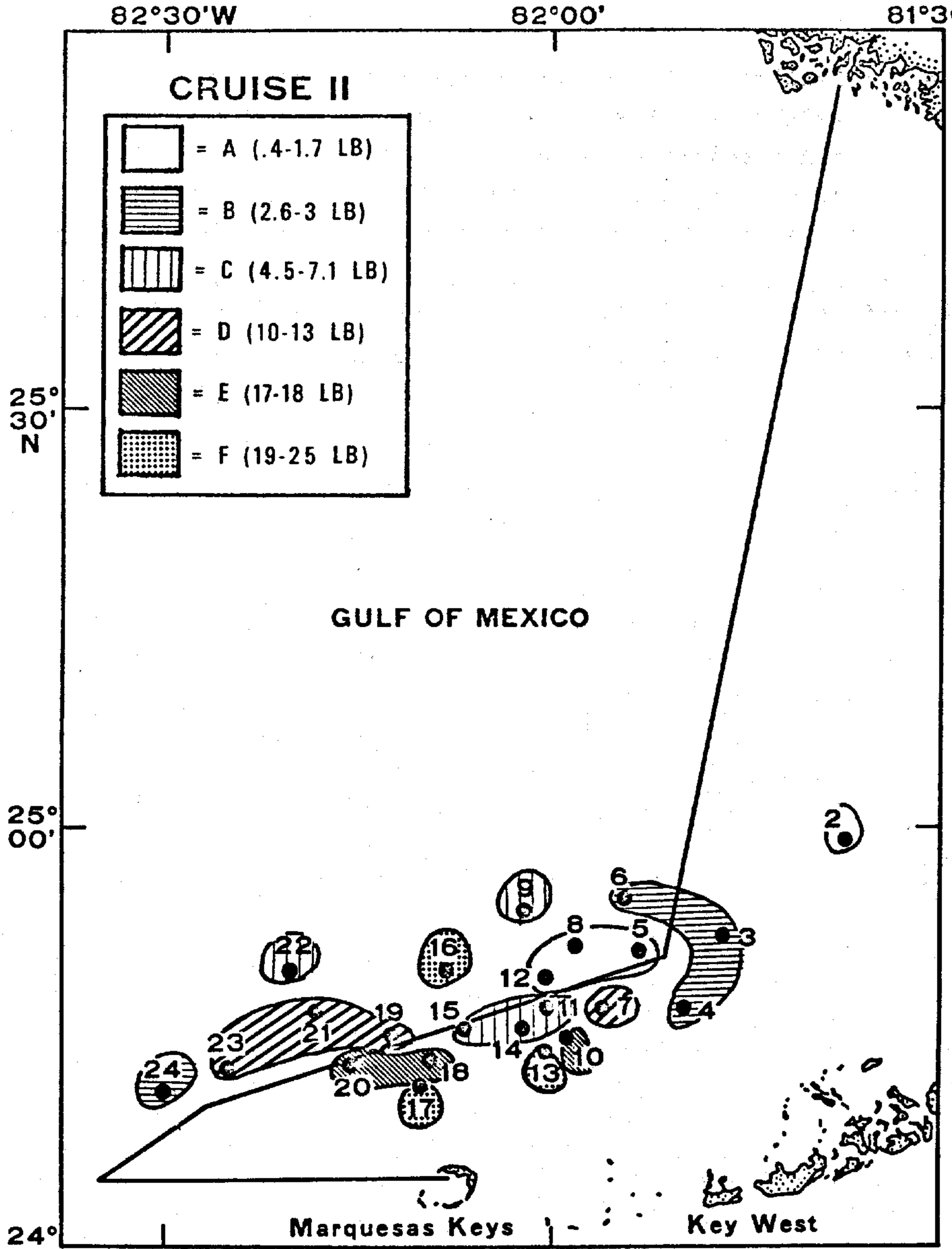

Figure 11. Sample stations grouped by the Student-Neuman-Keuls test according to mean shrimp weights occurring at each site of Cruise II (October 1981). Station F1 has been deleted.

Table 18. Results of a Student-Neuman-Keuls range test on shrimp weights at 23 stations of Cruise III. A square root transformation was used on weights data. Station F1 has been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Weigths ($\sqrt{lbs}$)	Nonsignificant Ranges Used
	9	1.01	A
	22	2.09	
	6	2.13	
	8	2.32	B
	20	2.61	
	16	2.90	
	12	3.19	
	23	3.21	
	21	3.49	C
	18	3.51	
	15	3.65	
	19	3.73	
	17	4.14	D
	24	4.16	
	3	4.70	
	11	4.89	
	5	4.92	
	13	4.97	E
	14	5.02	
	2	5.07	
	7	5.31	
	4	6.39	F
	10	6.73	

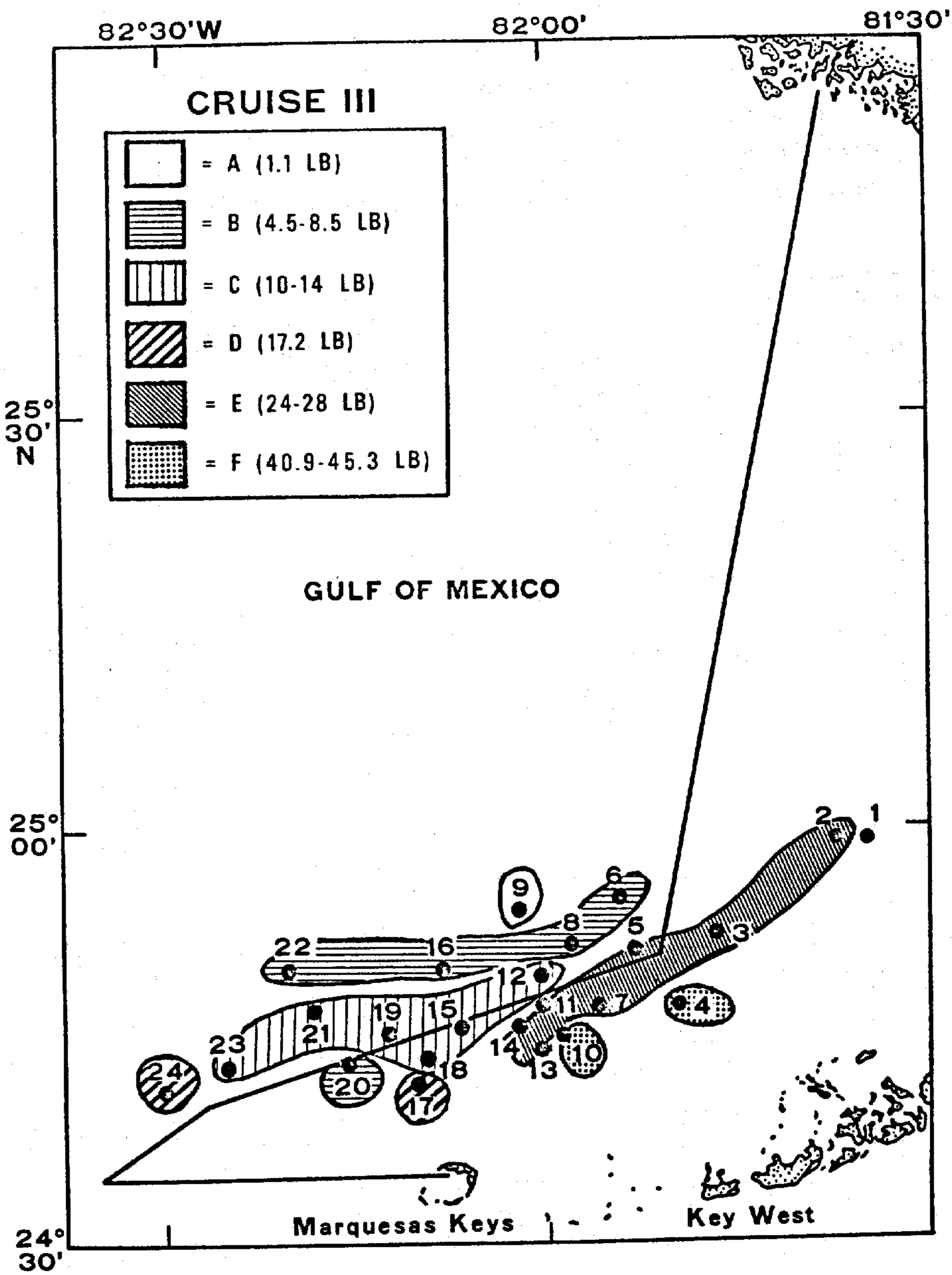

Figure 12. Sample stations grouped by the Student-Neuman-Keuls test according to mean shrimp weights occurring at each site of Cruise III (November 1981). Station F1 has been deleted.

increasing distance from the sanctuary. The only exceptions to this trend are Stations F17, F20, and F24.

Cruise IV (December 9-16, 1981)

Nine groups were initially identified for the December 1981 data (Table 19), but only five were used in Figure 13. The same overall trend occurs in these data, i.e. the highest CPUE (27-32 lbs) is found inside the sanctuary and the groups consist, for the most part, of stations scattered across the study area. Again, the stations with the highest CPUE (F3, F10, F13, F17) also had small to medium mean lengths (107.5-118 mm; see Fig. 7) in the December data. However, it should be noted that all stations during this cruise had shrimp with mean lengths of 106 mm or greater.

Cruise V (January 19-26, 1982)

The same general trends in CPUE distribution found in the four previous months are also found in January 1982. Six groups of the 11 identified in Table 20 are shown in Figure 14. The highest CPUEs (40-50 lbs) occur inside the sanctuary, but these high abundance stations (F7, F10, F11, F13, F18) also have small (93.5-107.5 mm) shrimp (see Fig. 8). The largest shrimp are found at stations with a CPUE of 15 lbs or much lower (Groups A, B, and C).

Cruise VI (February 18-24, 1982)

Only six groups are separated in the February 1982 data set (Table 21), five of which are shown in Figure 15. Stations F3, F7, and F11 inside the sanctuary have the highest CPUE (30-31 lbs), but F7 also belongs to a group in Figure 9 with a large mean length (108-111 mm). Otherwise, the same general pattern of an inverse relationship between CPUE and mean length is followed on this cruise.

Table 19. Results of a Student-Neuman-Keuls range test on shrimp weights at 21 stations of Cruise IV. A square root transformation was used on weights data. Stations F1, F21, F22 have been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Weigths ($\sqrt{lbs}$)	Nonsignificant Ranges Used
	2	1.47	A
	9	1.84	
	12	2.09	
	24	2.16	
	19	2.28	
	23	2.88	B
	4	3.01	
	16	3.30	
	7	3.51	C
	6	3.58	
	18	3.98	D
	14	4.01	
	15	4.10	
	5	4.52	
	20	4.52	
	11	4.56	
	8	4.67	
	13	5.20	E
	3	5.33	
	10	5.56	
	17	5.63	

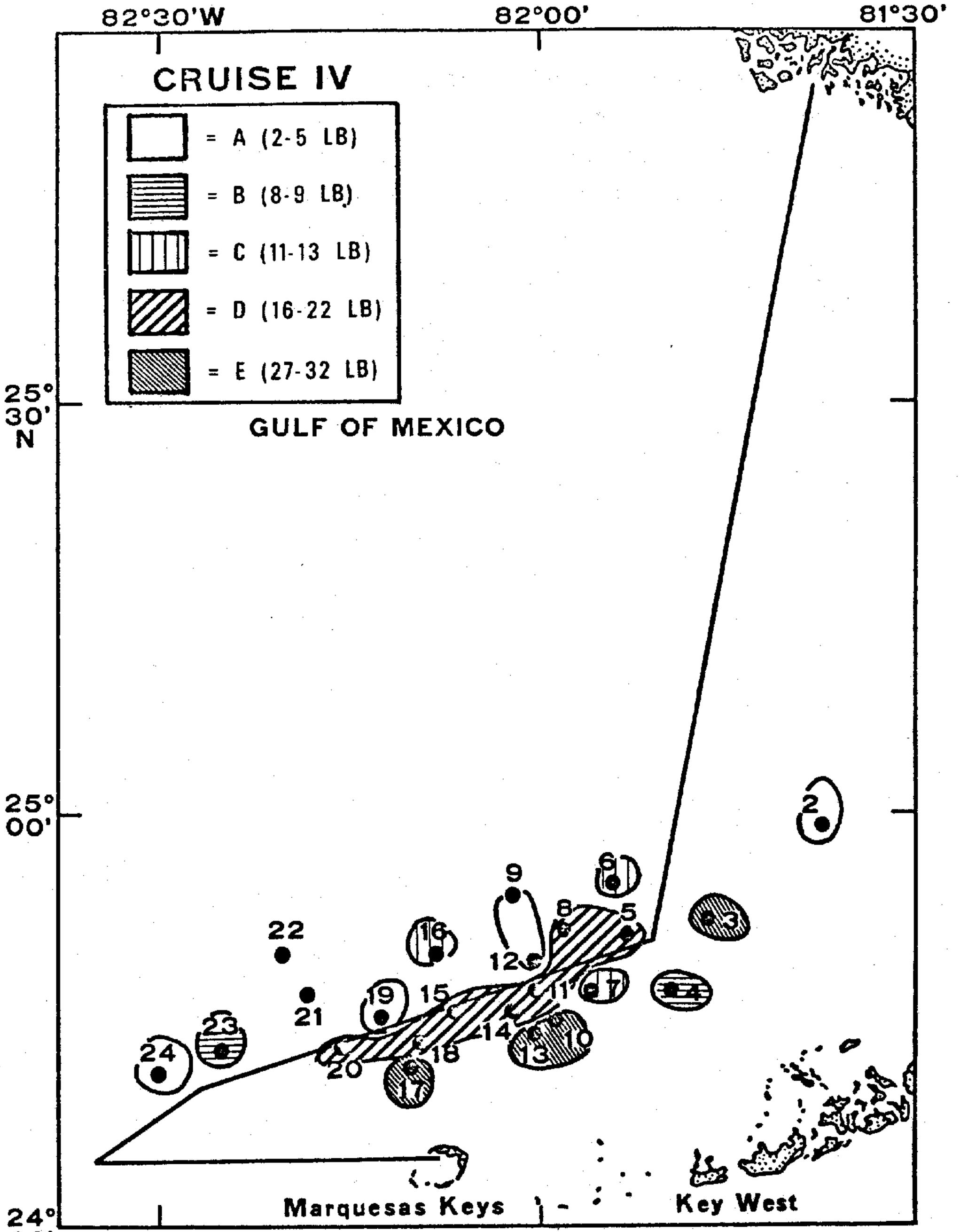

Figure 13. Sample stations grouped by the Student-Neuman-Keuls test according to mean shrimp weights occurring at each site of Cruise IV (December 1981). Stations F1, F21 and F22 have been deleted.

Table 20. Results of a Student-Neuman-Keuls range test on shrimp weights at 23 stations of Cruise V. A square root transformation was used on weights data. Station F1 has been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Weigths ($\sqrt{lbs}$)	Nonsignificant Ranges Used
	2	1.77	A
	12	2.10	
	9	2.14	
	16	2.64	B
	3	3.08	
	6	3.12	
	24	3.35	C
	19	3.36	
	8	3.75	
	4	3.90	
	20	4.58	D
	23	4.65	
	21	5.02	
	15	5.05	
	22	5.21	
	5	5.40	E
	14	5.70	
	17	5.98	
	11	6.32	F
	18	6.40	
	13	6.55	
	7	6.75	
	10	7.05	

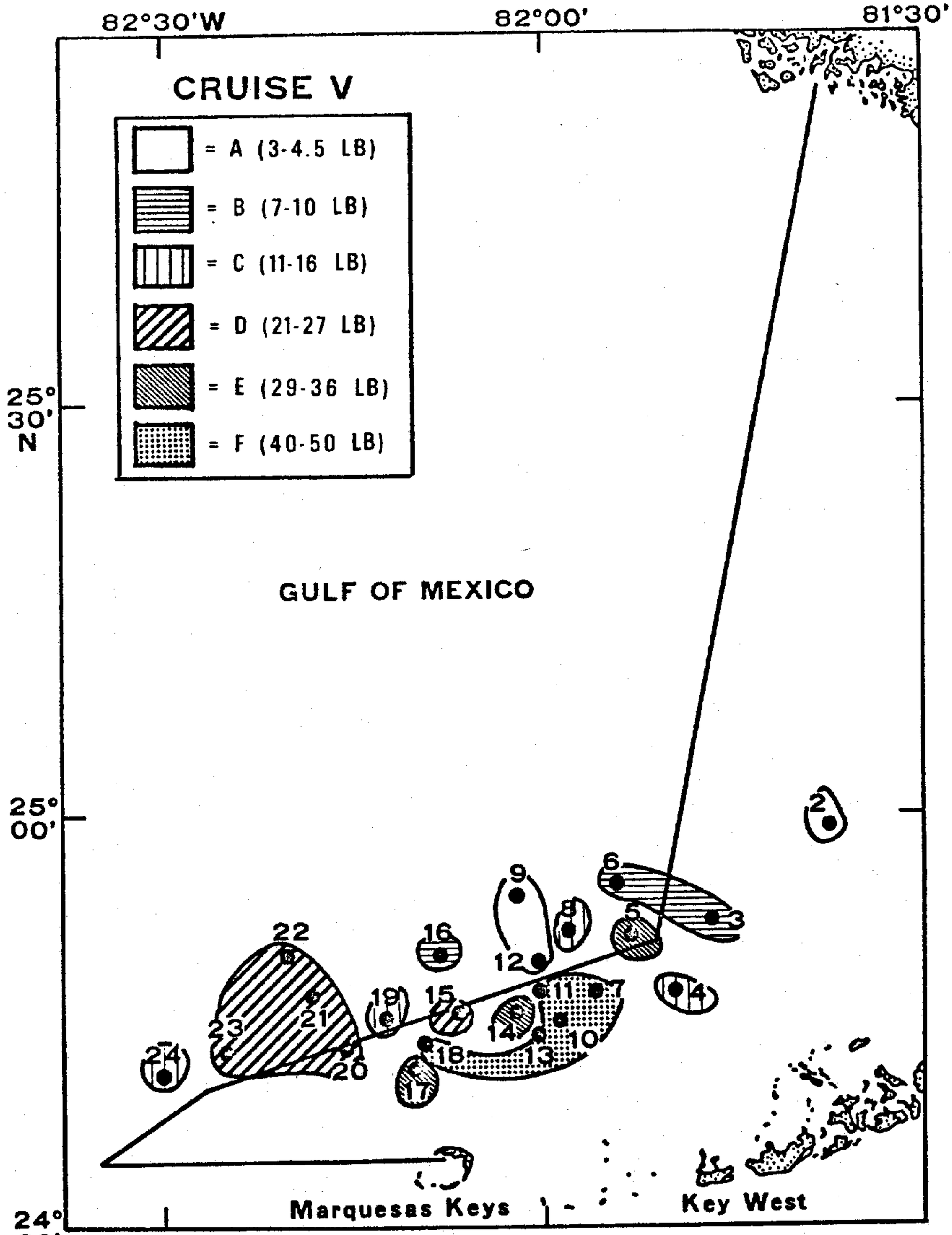

Figure 14. Sample stations grouped by the Student-Neuman-Keuls test according to mean shrimp weights occurring at each site of Cruise V (January 1982). Station F1 has been deleted.

Table 21. Results of a Student-Neuman-Keuls range test on shrimp weights at 23 stations of Cruise VI. A square root transformation was used on weights data. Station F1 has been deleted. Letters below nonsignificant ranges used refer to station groups shown on topographic maps.

Nonsignificant Station Groups	Station Number	Station Mean Weigths ($\sqrt{lbs}$)	Nonsignificant Ranges Used
	21	1.65	
	19	1.72	
	2	1.76	
	6	1.90	
	12	1.95	A
	11	2.10	
	8	2.12	
	9	2.17	
	22	2.44	
	24	2.47	
	16	2.53	
	18	3.03	
	20	3.10	B
	15	3.30	
	23	3.57	
	14	3.80	
	4	3.89	C
	17	3.96	
	5	4.03	
	13	4.52	D
	3	5.50	
	7	5.54	E
	10	5.56	

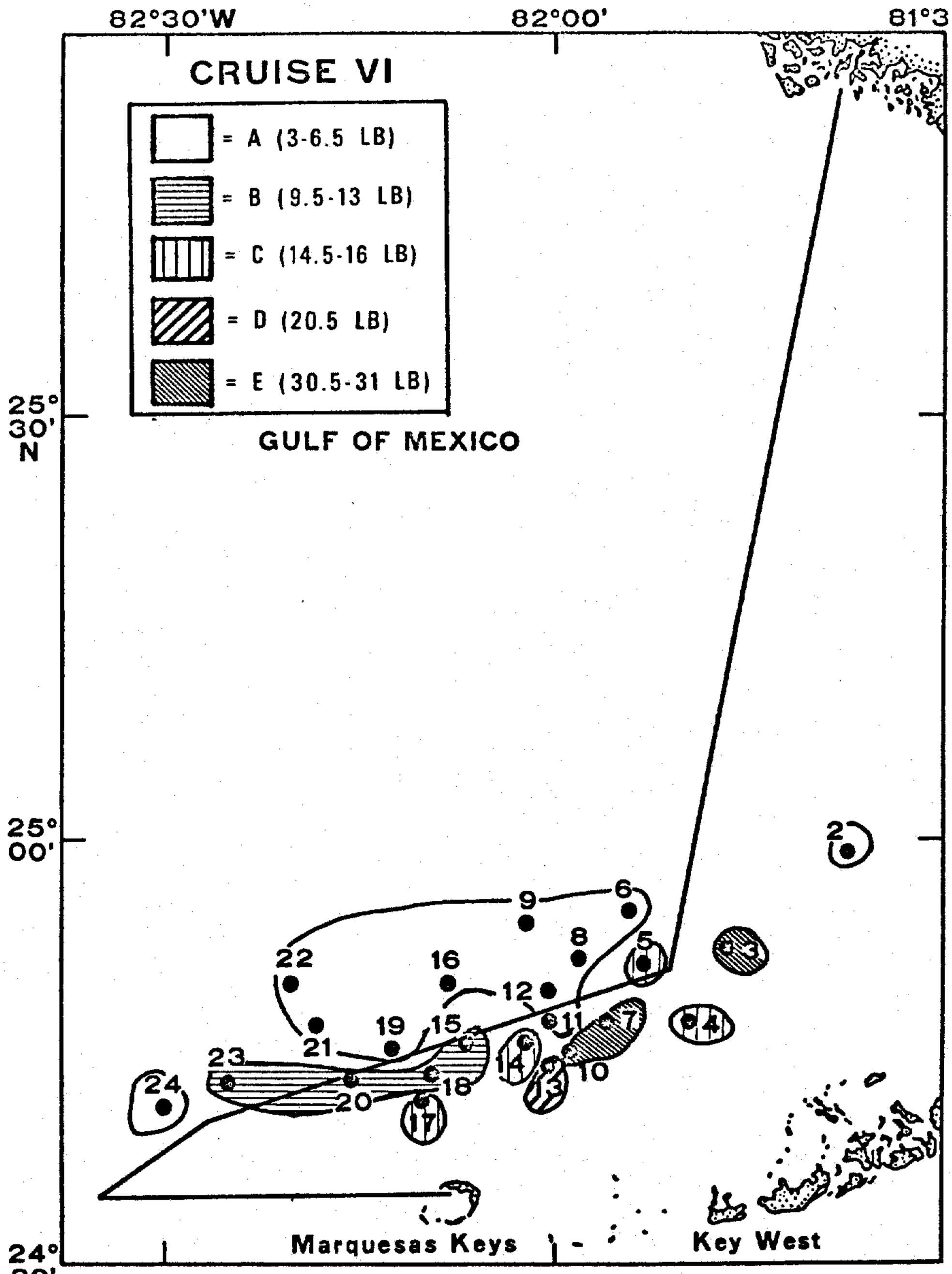

Figure 15. Sample stations grouped by the Student-Neuman-Keuls test according to mean shrimp weights occurring at each site of Cruise VI (February 1982). Station F1 has been deleted.

Discussion

Data for all six months of this study show the same general trends in CPUE distribution -- the highest CPUEs occur at stations inside the sanctuary (Table 22) and there is a general inverse relationship between CPUE and mean length.

Table 22 shows a range of average CPUEs inside the sanctuary of 11.03 lbs in October to 30.43 lbs in January. Outside the sanctuary the average CPUE varied from 6.4 lbs in October to 15.86 lbs in January, the low and high months for CPUE on both sides of the line.

Table 23 shows a more detailed break-down of CPUE at the sampling sites. In this table, stations were grouped according to three different ranges of CPUE. These ranges were arbitrarily chosen, but the lower limit of Group B was selected in an effort to show the minimum CPUE needed by most trawlers to just break even on expenses. This value, of course, is quite variable, but it does provide a base for this discussion. As shown in Table 23, most stations in the more profitable CPUEs (Groups B and C) are found inside the sanctuary in all months of the study. But, it should be remembered that most of these high CPUE stations inside the line are also populated by shrimp whose mean length is <103 mm (see Table 12 and Fig. 10-14). However, these small shrimp are less profitable to the shrimping industry and, as will be shown in the next section, commercial trawling would probably concentrate on those areas with larger shrimp which are also present inside the sanctuary.

The problem of explaining the high CPUE inside the sanctuary still remains. One possible explanation for the high CPUE inside the sanctuary is that the phenomenon may be related to fishing pressure. Heavy commercial pressure outside the sanctuary may reduce the shrimp population there. This fact could also partially

Table 22. Mean CPUEs (lbs/net/30 min. tow) and standard deviations of pink shrimp from both inboard nets of all stations inside and outside the sanctuary and all stations combined by month. Stations F3 and F20 (inside the line) in September have data from only one net and Stations F21 and F22 (outside the line) in December have no data.

	Inside Sanctuary		Outside Sanctuary		Combined Stations	
	CPUE	STD	CPUE	STD	CPUE	STD
September	19.96	15.52	9.25	4.95	14.84	12.88
October	11.03	8.56	6.40	5.65	8.82	7.67
November	23.92	10.96	10.16	6.26	17.34	11.36
December	19.25	8.60	9.92	6.69	14.68	9.26
January	30.43	15.51	15.86	9.17	23.46	14.79
February	17.25	9.75	6.81	4.52	13.58	8.90

Table 23. Summary of sample CPUE inside and outside the sanctuary line by month. The number in each weight class is the number of sampling stations in that weight range. The lower limit of Group B was chosen as an average lower limit for the break-even point for most trawlers in their CPUE. This was arbitrarily calculated as five to six boxes of shrimp (heads-on) per 10 hour night.

	Catch Per Unit Effort (lbs (heads-on)/net/30 min. tow)					
	Inside Sanctuary			Outside Sanctuary		
	A (<8 lbs)	B (8-20 lbs)	C (>20 lbs)	A (<8 lbs)	B (8-20 lbs)	C (>20 lbs)
September	3	4	5	6	5	0
October	6	4	2	7	4	0
November	1	3	8	4	6	1
December	1	5	6	4	3	2
January	1	2	9	3	4	4
February	2	6	4	9	2	0

explain the inverse relationship between CPUE and mean length since the shrimp fleet will concentrate where the larger and more profitable shrimp are located. Another possible explanation for lower numbers of large shrimp is that natural mortality and emigration will reduce the population in the study area over a period of time. Therefore, as the shrimp grow, fewer survive or remain in the area and their abundance decreases (immigration of shrimp back into the area will complicate this pattern, however). Thus, it is difficult to explain the distribution of shrimp abundance vs. size in the study area when the cause and effects of natural movement and mortality and fishing pressure are so difficult to separate and identify in these data.

Commercial Tows

The general position of the commercial tows for all six cruises in relation to the sampling stations are shown in Figure 16. The coordinates of the tows as well as the mean size of the shrimp, catch effort, count size, and percentage $\geq$103 mm are included in Table 24. It is evident from Figure 16 that there are three major concentrations of trawling activity located inside the sanctuary; around Station F10 between F7 and F13, between F13 and F18, and between F18 and F17. Since these are likely areas where commercial activity would concentrate if the sanctuary did not exist, the following discussion will focus on these areas.

The captain did not trawl in the primary areas under consideration during Cruise I, but concentrated his efforts around Stations F14 and F20. Station F20 was excluded from any analysis of mean length or CPUE during September because only one measured sample was available. However, commercial CPUE around F20 varied from 12.5-21.7 lbs and mean length was 103-116 mm. The shrimp in commercial tows were smaller at F14 (95-98 mm), but the CPUE was

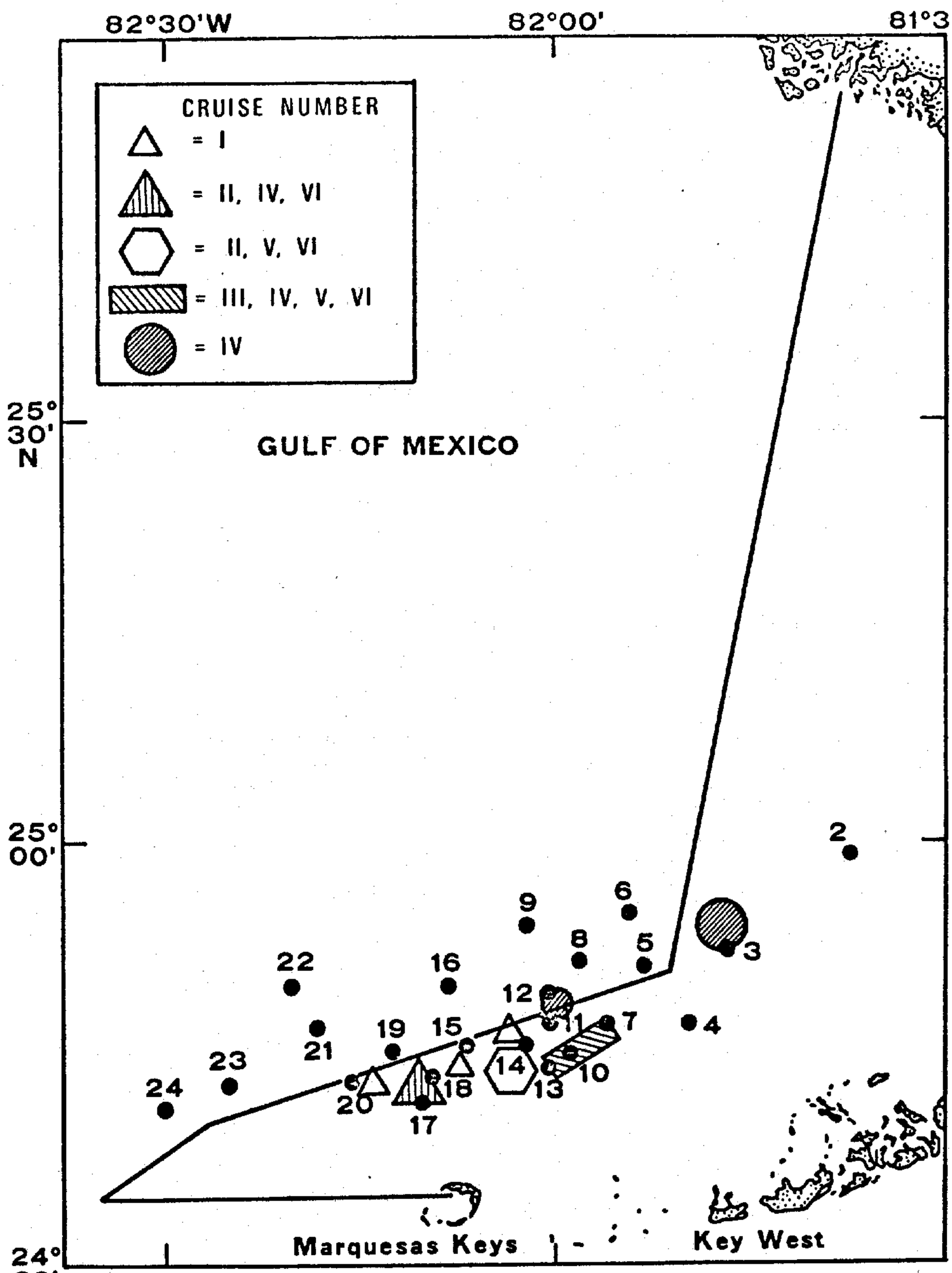

Figure 16. Locations of primary trawling sites of the commercial tows made during all six cruises in relation to the sampling stations.

Table 24. Station number and coordinates, CPUE, shrimp mean length, percentage of shrimp ≥103 mm total length, and count size for all commercial tows of all cruises.
*Data for Station 107 of Cruise VI taken from only three nets.

Station	Total Shrimp Weight (lbs)	Towing Time (hrs)	CPUE (lbs/net/30 min)	Latitude (° ' N)	Longitude (° ' W)	Mean Length (mm)	Shrimp ≥103 mm (%)	Count Size (Heads-on/lb)
				Cruise I				
101	520	3.0	21.7	24 42	82 15	116	83	33
102	200	2.0	12.5	24 42	82 13	107	53	42
103	250	1.5	20.8	24 41	82 14	103	46	47
104	600	3.0	25.0	24 46	82 02	98	25	55
105	450	2.0	28.1	24 46	82 02	96	18	58
106	400	2.0	25.0	24 46	82 03	95	18	60
107	250	3.0	10.4	24 44	82 07	112	74	37
108	400	3.0	25.0	24 44	82 07	103	43	47
				Cruise II				
101	420	2.5	21.0	24 43	82 06	120	78	30
102	200	1.75	14.3	24 43	82 06	112	69	37
103	100	1.5	8.3	24 43	82 06	115	72	34
104	200	3.0	8.3	24 42	82 09	112	60	37
105	350	3.5	12.5	24 42	82 10	116	69	33
106	310	3.75	10.3	24 43	82 10	117	73	32
107	440	3.0	18.3	24 43	82 04	103	46	47
108	360	3.75	12.0	24 44	82 09	116	72	33
109	210	3.0	8.8	24 44	82 11	112	66	37
110	390	3.5	13.9	24 44	82 09	111	61	38

Table 24 (Continued)

Station	Total Shrimp Weight (lbs)	Towing Time (hrs)	CPUE (lbs/net/30 min)	Cruise III Latitude (° ' N)	Longitude (° ' W)	Mean Length (mm)	Shrimp ≥103 mm (%)	Count Size (Heads-on/lb)
101	600	3.0	25.0	24 45	81 59	101	43	50
102	420	2.5	21.0	24 47	81 58	110	67	39
103	600	3.0	25.0	24 44	81 59	105	49	44
104	600	3.0	25.0	24 45	81 56	107	52	42
105	660	4.0	20.1	24 44	81 59	103	41	47
106	750	3.75	25.0	24 44	82 01	102	41	49
107	660	3.5	23.6	24 45	81 56	108	55	41
108	540	3.25	20.8	24 45	81 56	105	48	44
109	380	2.0	23.8	24 45	81 56	102	44	49
110	560	3.0	23.3	24 46	81 57	105	52	44
111	600	4.0	18.8	24 46	81 57	108	58	41
				Cruise IV				
101	300	3.5	10.7	24 54	81 47	112	75	37
102	360	3.5	12.9	24 54	81 46	110	72	39
103	480	3.5	17.1	24 53	81 47	107	56	42
104	600	3.5	21.4	24 53	81 47	108	55	41
105	300	3.5	10.7	24 53	81 47	104	52	46
106	570	3.5	20.4	24 42	82 11	114	76	35
107	435	3.0	18.1	24 42	82 11	108	63	41
108	540	3.5	19.3	24 42	82 11	116	82	33
109	330	3.0	13.8	24 43	82 10	110	67	39
110	780	4.5	21.7	24 44	81 56	110	68	39
111	840	4.0	26.3	24 48	82 00	108	62	41
112	540	4.5	15.0	24 45	81 58	109	61	40

Table 24 (Continued)

Cruise V

Station	Total Shrimp Weight (lbs)	Towing Time (hrs)	CPUE (lbs/net/30 min)	Latitude (° ' N)	Longitude (° ' W)	Mean Length (mm)	Shrimp ≥103 mm (%)	Count Size (Heads-on/lb)
101	680	2.5	34.0	24 45	81 57	105	46	44
102	260	1.5	21.7	24 46	81 57	107	50	42
103	540	2.0	33.8	24 45	81 57	106	55	43
104	720	3.0	30.0	24 45	81 57	112	61	37
105	660	3.0	27.5	24 45	81 57	104	45	46
106	540	3.0	22.5	24 45	81 58	108	57	41
107	660	3.0	27.5	24 45	81 58	111	62	38
108	600	3.0	25.0	24 45	81 58	106	52	43
109	600	3.0	25.0	24 44	82 00	103	47	47
110	480	3.0	20.0	24 44	82 04	110	62	39
111	600	3.0	25.0	24 44	82 05	112	67	37
112	600	3.5	21.4	24 44	82 05	106	53	43
113	680	3.5	24.3	24 44	82 05	107	55	42
114	480	3.0	20.0	24 44	82 05	115	70	34

Table 24 (Continued)

Cruise VI

Station	Total Shrimp Weight (lbs)	Towing Time (hrs)	CPUE (lbs/net/30 min)	Latitude (° ' N)	Longitude (° ' W)	Mean Length (mm)	Shrimp ≥103 mm (%)	Count Size (Heads-on/lb)
101	400	2.0	25.0	24 45	81 59	103	47	47
102	300	2.5	15.0	24 45	81 55	100	41	51
103	420	3.5	15.0	24 45	81 55	112	58	37
104	500	3.5	17.9	24 45	81 55	104	48	46
105	400	3.5	14.3	24 45	81 55	102	43	49
106	420	3.5	15.0	24 45	81 55	113	62	36
*107	200	3.5	9.5	24 45	81 55	97	34	56
108	76	1.5	6.3	24 44	81 58	100	35	51
109	250	3.0	10.4	24 42	82 10	101	41	50
110	150	1.5	12.5	24 43	82 04	105	49	44
111	300	3.0	12.5	24 44	81 59	99	36	53
112	250	2.0	15.6	24 44	81 56	95	29	60
113	550	3.5	19.6	24 44	81 56	95	29	60
114	450	3.5	16.1	24 45	81 58	99	35	53
115	420	3.5	15.0	24 44	81 56	93	26	64

higher (25-28.1 lbs) than at F20. The mean size of commercially caught shrimp is equivalent to the study samples at F14 (96 mm), but commercial CPUE (25-28.1 lbs) is less than the sample CPUE (40.5 lbs).

The same general trends established during Cruise I hold true for the other five cruises in the three areas of activity: the mean length of the commercial catch was equivalent to the mean length of the samples at the nearest stations, but commercial CPUE, for the most part, was less than the sample CPUE. The relationship between commercial CPUE and sample CPUE was variable, but in general, the commercial catch was less than the sample catch. There is no satisfactory explanation in the data for this phenomenon, but one possibility is the fact that few of the commercial tows coincided with the actual station location and sometimes one or more nights may separate the trawling times between the commercial visits and the sampling visits. Therefore, there could be a spatial as well as a temporal factor involved in the differences between the CPUEs. Another possibility is the fact that commercial tows usually had a towing time of 2.5-3.5 hours and the entire tow may not have been over the most productive bottom.

Although the mean lengths of most of the commercially caught shrimp for the six cruises were greater than 103 mm, shrimp under 103 mm were sometimes taken in great abundance (16 of 70 commercial tows had catches with mean lengths <103 mm). In the past, these smaller shrimp would be discarded by the practice of culling. However, with the appearance of freezer boats in the shrimp fleet, these smaller shrimp are no longer discarded since they can be frozen whole on board and then processed at the large land-based processing plants using modern technology which wastes very little of the shrimp. The MV MISS VIRGINIA is a freezer boat and, although smaller shrimp bring a lower price, these shrimp were retained rather than being lost through the practice of culling (see Costello (MS) for a discussion of culling).

The important thing to note in Table 24 is that when given a choice of trawling area, the captain was able to catch shrimp over the Florida legal limit 77% of the time inside the sanctuary. Of course this figure will be variable with respect to time and probably would also change if there were unrestricted commercial activity in the sanctuary. But it is evident in these data that there is a concentration of legal-sized shrimp inside portions of the sanctuary during the study period. Also, it is evident that the captain concentrated on those areas with larger shrimp based on his prior knowledge and on the sample data collected during the cruise.

HYDROGRAPHY

The measured hydrographic parameters of surface and bottom temperature and salinity are presented in Figure 17 to characterize the environment of the study area for the period September 1981 to February 1982. Except for the months of October and November (Cruises II and III), salinity at the surface and near bottom never fluctuated beyond 34 o/oo-36 o/oo, indicating a nearly uniform salinity regimen in the study area. In October, Station F4 surface salinity reached 37 o/oo and Stations F9 and F14 bottom salinities reached 38 o/oo and 37 o/oo, respectively. No cause for this variation was apparent in the data or in the location of the stations. Nevertheless, these slightly higher salinity values are of little environmental consequence since pink shrimp are normally exposed to larger fluctuations in the shallow bays, where they mature before moving to deeper water.

During November 1981, a bottom salinity of 38 o/oo was recorded at Station F8. Again, no cause for this higher value could be determined, and it may have been a recording error. Station F23 on this cruise is especially suspect as having incorrect readings. Both temperature and salinity readings at the surface and near bottom were anomalously lower than usual and probably should be

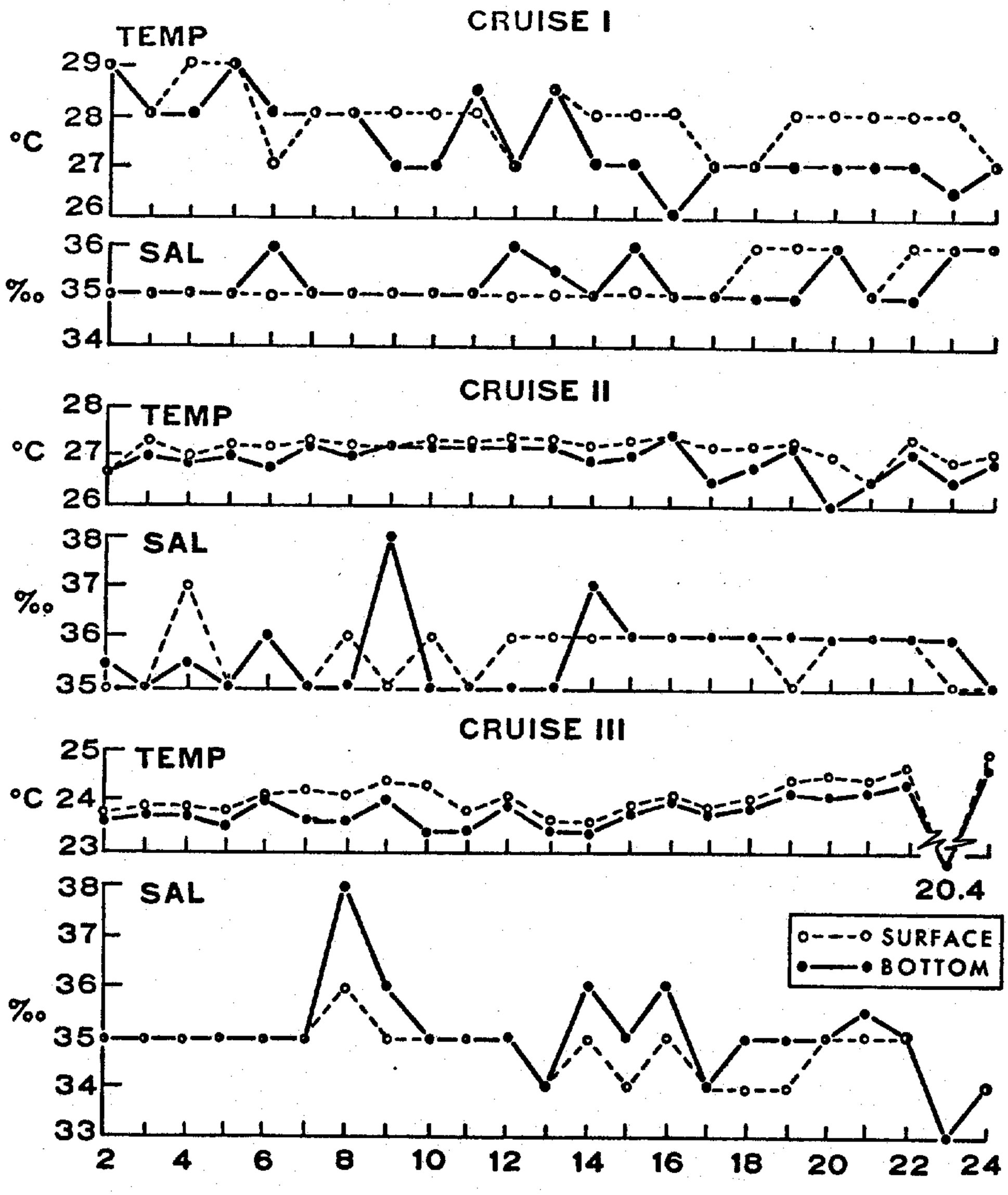

Figure 17. Salinity and temperature measurements of the surface and near bottom at each station (excluding F1) at all cruises. See text for an explanation of anomalous readings at F23 of Cruise III.

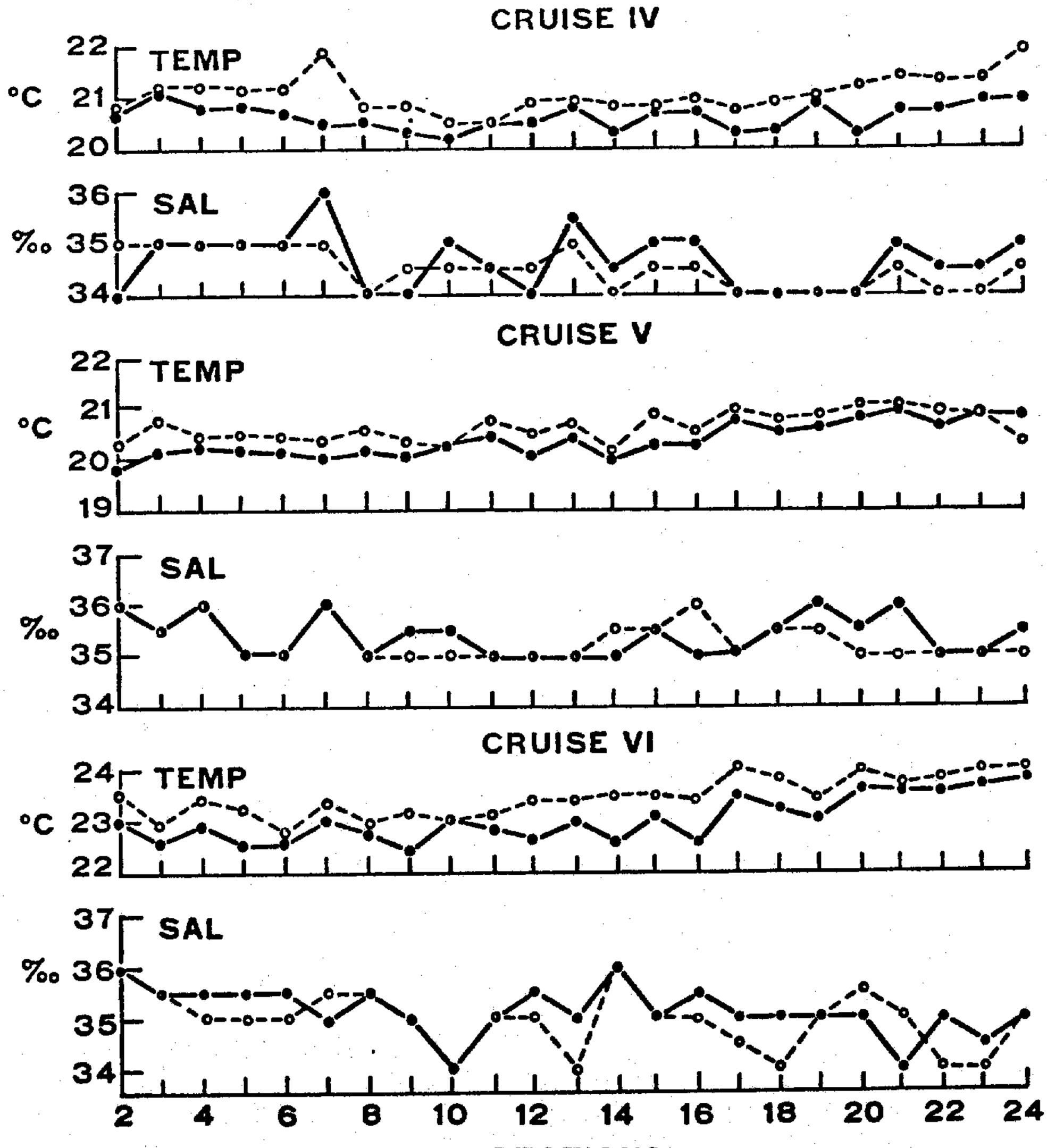

Figure 17 (Continued)

disregarded. A cold front or an upwelling event could explain the temperature drop, but no cold front came through at that time. Also, to our knowledge there are no past records of upwelling events in this locality.

Temperature was also very uniform at all stations during any one cruise, with a nearly uniform temperature from surface to bottom at all depths (6-14 fathoms) in the study area. Only one anomalous temperature was recorded and that was at Station F23 of Cruise III that has been described previously.

The greatest fluctuations in temperature occurred during September 1981 and that was only 3°C between lowest and highest readings of surface and bottom values. Otherwise, temperature never fluctuated more than 1.7°C during a cruise. However, temperatures between cruises did vary according to season. The average water temperature was highest in September (28°C) and dropped each month until January (20.5°C). February water temperatures had risen to about 23°C during Cruise VI.

It appears from the above data that neither temperature nor salinity vary enough to be responsible for any size or density discontinuities in shrimp distributions in the study area. However, temperature may have a seasonal rather than a direct effect on shrimp movements, in general, as described by Ingle et al. (1959) and Eldred et al. (1961).

OVARIAN DEVELOPMENT

Gross maturity stages of female pink shrimp were checked in the field during routine length measurements by macroscopic examination of the ovaries. The following stages of development were used and represent a modification of the stages used by Joyce (1965).

Stage 1 - Undeveloped to beginning development. Ovaries clear and small to opaque and slightly enlarged.

Stage 2 - Developing to developed. Ovaries turning yellowish and enlarged to bright yellow and near maximum size.

Stage 3 - Ripe. Ovaries slightly greenish to olive green and at maximum size.

Stage 4 - Spent. Ovaries sometimes yellowish and small in size.

We found no positive evidence of Stage-4 individuals in our samples, probably due to inexperience in detecting differences between Stage-2 and Stage-4. Joyce (1965) also encountered difficulties in determining Stage-4 individuals, at least during the early part of his sampling.

Figure 18 shows ovarian maturity stages for samples from 23 stations of each cruise. An overall comparison of the cruises indicates there is a greater proportion of developing and developed females in September and October. This timing coincides with the highest water temperatures (28°C and 27°C, respectively). The greatest numbers of shrimp in advanced stages during these months also occur at the deeper stations (F17, F18, F20, F21, F22, F23, and F24) near the western end of the study area (8-14 fathoms). This finding agrees with previous research by Munro et al. (1968) who found spawning throughout the year in the Tortugas area at temperatures of 19°C to 30°C, but mostly when temperatures exceeded 25°C. They also found that the center of spawning activity moved to deeper waters from spring to fall.

The lowest occurrences of advanced maturity stages were in November (24°C) and December (21°C) 1981. This reduced reproductive activity due to lower water temperature also follows Munro et al.'s (1968) hypothesis. Although the month of January had a slightly lower water temperature (20.5°C), an increasing proportion of developing females were noted. This pattern of increasing female maturity continued in February 1982 which had increasing

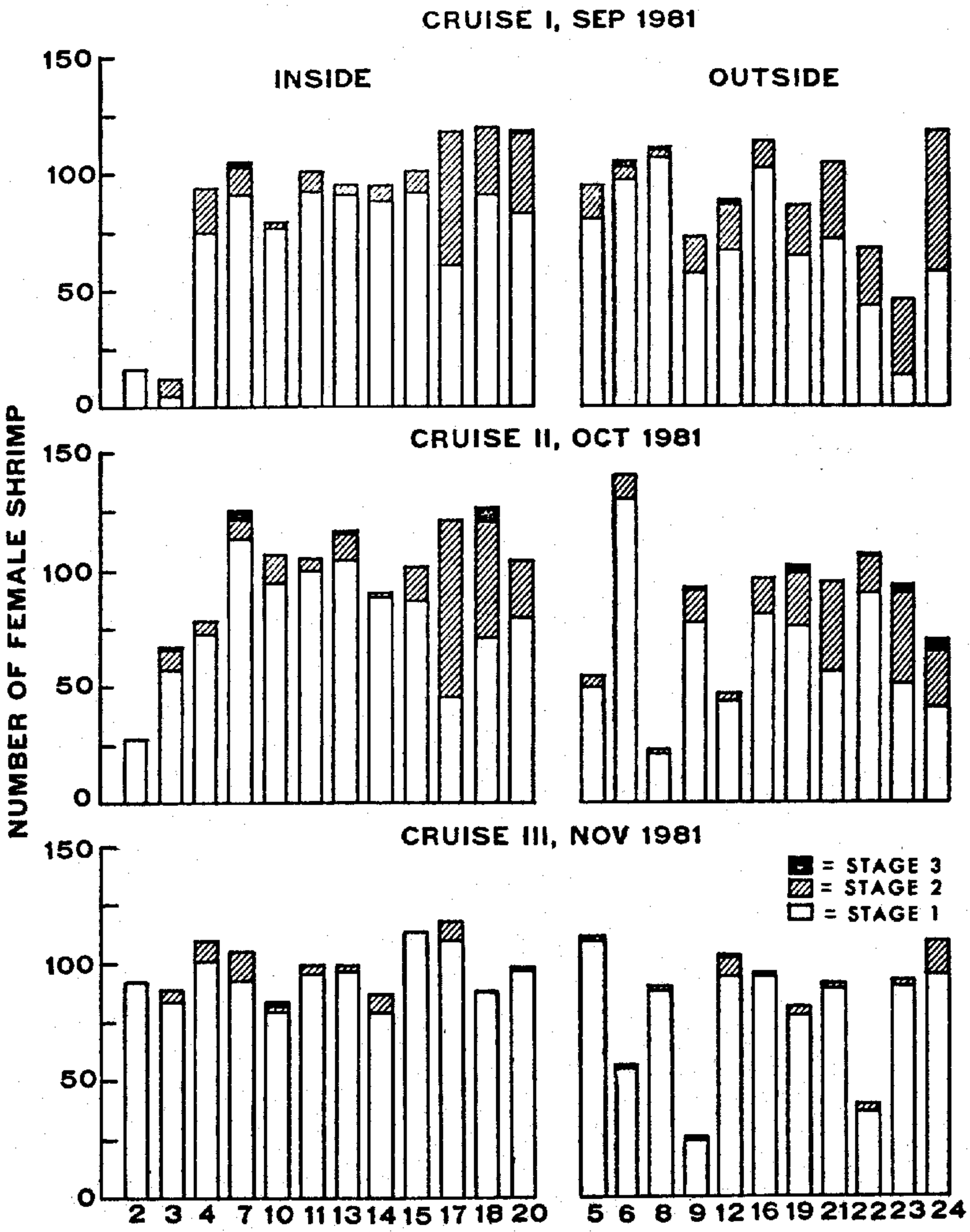

Figure 18. Graphs of pink shrimp ovarian development stages at each station (excluding F1) of all cruises.

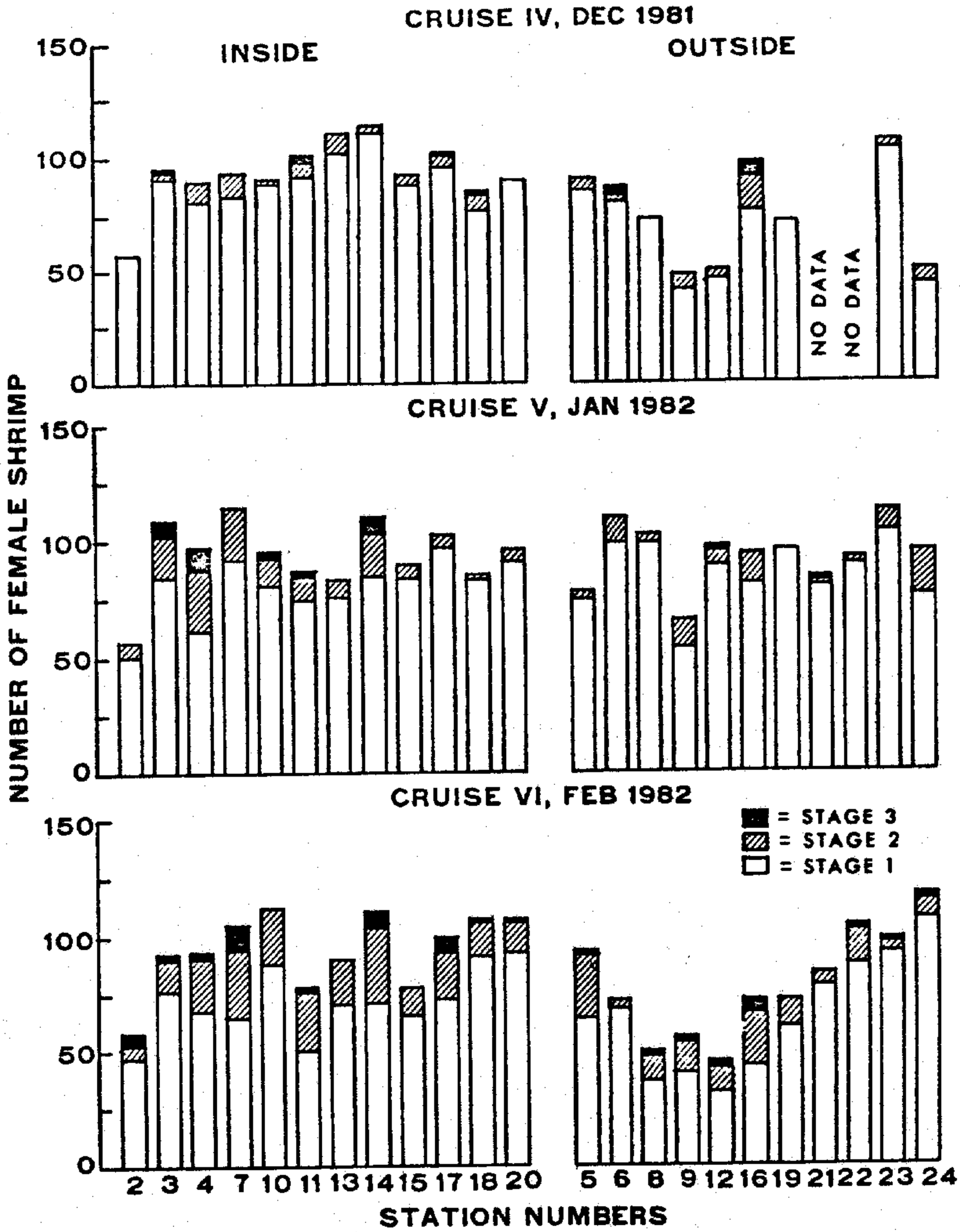

Figure 18 (Continued)

water temperatures averaging 23°C. This increase in female maturity in January is corroborated by Eldred et al. (1961) in their data, and Munro et al. (1968) further state that maturing shrimp spawn when they reach a suitable size irrespective of water temperature at the Tortugas site. Therefore, even with spawning occurring year-round in the study area, there are peaks of increased spawning activity. January represents the start of the spring peak and the low water temperatures recorded then represent only specific points in time. Water temperatures over the entire month probably were increasing, leading to the higher February readings. It should be noted, however, that the advanced maturity stages occurred throughout the study site in January and February with no particular depth predominating.

Munro et al. (1968) also reported that their spawning data appeared to correlate with moon phase, with highest activity occurring during the last half (waning) of the lunar month. With the exception of Cruise IV (December), all of the data were collected during the last half or peak lunar period. Therefore, December's results may have been altered had the data been collected during the same part of the lunar month as the other cruises.

SUMMARY

1. Twenty-three stations located inside and outside the Tortugas Shrimp Sanctuary were sampled once a month from September 1981 to February 1982 by NMFS personnel on board the MV MISS VIRGINIA, a Florida-based shrimp trawler. Hydrographic data and shrimp samples were collected at each station in order to characterize the marine environment and to better define the distribution and size frequencies of pink shrimp in and around the sanctuary.

2. Four nets were towed simultaneously and analysis of variance indicated there was no statistical difference between the weight of the shrimp catch in each net. As a result, the data were combined and mean values were used for further analysis. Two-way anova did reveal highly significant differences in the mean shrimp lengths between cruises, between stations, and in the interaction between cruises and stations. One-way anova of each cruise also indicated a highly significant difference in the mean shrimp lengths between stations of each cruise. Student-Neuman-Keuls step-wise multiple range test separated the station means into similar groups for analysis of size distribution.

3. The major objective of this study was to define the distribution of small pink shrimp in the Tortugas fishery so that the sanctuary boundaries may be modified, if needed, to better protect the small shrimp and allow them to mature to a marketable size. The results of the Student-Neuman-Keuls tests for the first six months of the study reveal a complex and variable shrimp distribution in the area. Similar distributions with

shrimp size increasing from east to west in the study area were noted during September and October. November data, however, show small shrimp (<103 mm) at the eastern stations and large shrimp at the middle stations. In December, larger shrimp (≥ 106 mm) were dominant at all stations. January and February show a reversal in the earlier size trends with larger shrimp now occurring at the eastern (shallow) stations and smaller shrimp at the western (deep) end. In each month, shrimp with mean lengths above and below 103 mm, the Florida legal limit, could be found inside as well as outside the sanctuary. Shrimp abundance (small and large shrimp) was highest inside the sanctuary with small shrimp comprising 50% or more of the population in every month except December. Large shrimp dominate the population outside the sanctuary except in January and February. It appears, therefore, that the sanctuary does protect the greater portion of the small shrimp population, but the sanctuary boundaries do not represent a clear-cut demarcation between large and small shrimp. Based on this evidence, the sanctuary does not protect the entire "nursery" area at all times, and it also includes areas with large shrimp inside the boundaries.

4. Catch per unit effort (CPUE) is defined in this study as the weight of shrimp caught in one 40 ft net during a 30 minute tow. Student-Neuman-Keuls tests on the anova for each cruise indicate a complex distribution of shrimp density across the study area. In general, the data from all six cruises displayed the same trends. Highest CPUEs occurred at stations inside the sanctuary and a general inverse relationship existed between CPUE and mean length. The highest CPUEs (as high as 50-55 lbs) usually were found at Stations F10, F13, F14, and

F17, whereas the lowest CPUEs (0.2-1.0 lbs) usually occurred at Station F2 inside the line and at various other stations outside the line.

5. The commercial tows taken by the captain of the MV MISS VIRGINIA generally clustered in the areas near Stations F10, F13, F14, and F17. The mean size of shrimp from the commercial tows were generally equivalent to the mean size of samples taken at the nearest station. Commercial CPUE, however, was usually less than the sample CPUE taken at the nearest station. Although the commercially caught shrimp were mostly larger than 103 mm, 16 of the 70 commercial tows from all six cruises contained shrimp whose mean lengths were less than 103 mm. These shrimp were not discarded, but were retained with the rest of the catch.

6. Salinity and temperature were measured at the surface and near bottom of each station for each cruise. Salinity did not vary beyond 34 o/oo-36 o/oo, except on a few occassions when it did reach as high as 38 o/oo and as low as 33 o/oo. This last value is thought to be an incorrect reading and should be disregarded. Temperature was also essentially uniform between surface and bottom at all stations on any one cruise, but it did vary between cruises. Temperature usually never fluctuated more than 1.7°C during a cruise, except for September when there was a 3°C fluctuation. Water temperature was highest in September (28°C average) and lowest in January (20.5°C average). These parameters indicate that the study area has a nearly uniform environment with regard to temperature and salinity; and changes occur mostly according to seasonal effects or occassional short-term effects (e.g. cold-fronts).

7. Macroscopic examination of shrimp ovaries revealed a pattern of reproduction in agreement with previous studies (e.g., Eldred et al., 1961; Munro et al., 1968). The warmest months of the study (September and October) had the highest percentages of females with advanced ovarian development. Lower percentages occurred when water temperature dropped below 25°C. However, January showed an increase in ovarian development over December even though water temperature was lowest in January (20.5°C). February continued the trend of increasing development and increasing water temperature. This corresponds to the beginning of the spring peak in the spawning cycle (Eldred et al., 1961).

LITERATURE CITED

Costello, T. J. (MS). A historic review of State of Florida regulations relating to the Tortugas pink shrimp fishery and the rationale underlying these regulations. Unpublished Manuscript.

Eldred, B., R. M. Ingle, K. D. Woodburn, R. F. Hutton, and H. Jones. 1961. Biological observations on the commercial shrimp, Penaeus duorarum Burkenroad, in Florida waters. Fla. State Bd. Conser., Prof. Pap. Ser., No. 3:1-139.

Fontaine, C. T. and R. A. Neal. 1971. Length-weight relations for three commercially important penaeid shrimp of the Gulf of Mexico. Trans. Amer. Fish. Soc. 100(3):584-586.

Gulf of Mexico Regional Fishery Management Council. 1980. Fishery management plan for the shrimp fishery of the Gulf of Mexico. Fed. Reg. 45(218):74190-74308.

Ingle, R. M., B. Eldred, H. Jones, and R. F. Hutton. 1959. Preliminary analysis of Tortugas shrimp sampling data, 1957-1958. Fla. State Bd. Conser., Tech. Ser. 36:1-45.

Iversen, E. S. and C. P. Idyll. 1960. Aspects of the biology of the Tortugas pink shrimp, Penaeus duorarum. Trans. Amer. Fish. Soc. 89(1):1-8.

_____ and A. C. Jones. 1961. Growth and migration of the Tortugas pink shrimp, Penaeus duorarum, and changes in the catch per unit of effort of the fishery. Fla. State Bd. Conser., Tech. Ser. 34:1-30.

_____, A. E. Jones, and C. P. Idyll. 1960. Size distribution of pink shrimp, Penaeus duorarum, and fleet concentrations on the Tortugas fishery grounds. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. No. 356:1-62.

Joyce, E. A., Jr. 1965. The commercial shrimps of the northeast coast of Florida. Fla. State Bd. Conser., Prof. Pap. Ser., No. 6:1-224.

Munro, J. L., A. C. Jones, and D. Dimitriou. 1968. Abundance and distribution of the larvae of the pink shrimp (Penaeus duorarum) on the tortugas shelf of Florida, August 1962-October 1964. Fish. Bull. 67(1):165-181.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. The principles and practice of statistics in biological research. W. H. Freeman & Company, San Francisco, 776 pp.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics with special reference to the biological sciences. McGraw-Hill Book company, Inc., New York, 481 pp.

Taylor, L. R. 1961. Aggregation, variance, and the mean. Nature 189(4766):732-735.

APPENDIX

The following data consist of numbers of shrimp caught at Stations F3-F24 and were used to calculate Tables 11, 12, and 13. The number of shrimp at each station was calculated by determining the weight of shrimp caught in all four nets and then multiplying by the number of shrimp per pound for that sample. A 3 lb. count was determined for each station. If a station did not have data from four nets, then the weight that would have been obtained had all four nets been used was calculated. The percentage of shrimp in each sample that was $<$103 mm and $\geq$103 mm was determined from the combined length/frequency histograms determined from measurements of shrimp in the inboard nets. The numbers of shrimp for stations F3-F20 in the upper half of the table were summed and the total given at the bottom of the column for Inside Sanctuary. This procedure was then repreated for stations F5-F24 in the lower half of the table and the total was given for the Outside Sanctuary value. Stations F1 and F2 were deleted for reasons explained in the text. The values in brackets for F21 and F22 of Cruise IV were calculated as an average from all the outside sanctuary stations for December since those data were not taken.

Cruise I, September 1981

Number of Shrimp/Station

Station	‹103	›103	Totals
3	21.79	39.96	61.75
4	3425.91	1854.09	5280.00
7	1776.98	827.02	2604.00
10	10316.67	1187.33	11504.00
11	746.27	567.73	1314.00
13	2908.71	1767.29	4676.00
14	8235.42	1526.58	9762.00
15	1612.32	1391.68	3004.00
17	861.13	3150.87	4012.00
18	1232.11	1697.89	2930.00
20	623.75	1200.25	1824.00
5	887.18	558.82	1446.00
6	1523.49	808.51	2332.00
8	900.07	331.93	1232.00
9	148.43	265.57	414.00
12	539.34	636.66	1176.00
16	1373.46	1106.54	2480.00
19	599.61	1114.39	1714.00
21	538.06	4757.94	5296.00
22	90.18	585.82	676.00
23	59.73	284.27	344.00
24	249.35	1346.65	1596.00
Inside	31761.07	15210.68	46971.75
Outside	6908.90	11797.10	18706.00
Total	38669.97	27007.78	65677.75

Cruise II, October 1991

Number of Shrimp/Station

Station	‹103	›103	Totals
3	248.00	150.00	398.00
4	374.61	225.30	599.91
7	1244.10	734.57	1978.67
10	1955.14	1388.64	3343.78
11	983.91	528.09	1512.00
13	2842.64	2377.86	5220.50
14	604.30	330.49	934.79
15	326.43	550.57	877.00
17	403.37	1416.63	1820.00
18	870.88	1739.46	2610.33
20	208.46	703.54	912.00
5	167.14	118.92	286.06
6	325.94	141.66	467.60
8	72.90	11.60	84.50
9	259.95	351.05	611.00
12	100.99	73.01	174.00
16	1841.59	1648.10	3489.68
19	154.65	1399.61	1554.26
21	180.95	1468.87	1649.82
22	379.79	307.01	686.80
23	114.33	1255.87	1370.20
24	63.60	266.40	330.00
Inside	10061.83	10145.15	20206.98
Outside	3661.84	7042.08	10703.92
Total	13723.67	17187.23	30910.90

Cruise III, November 1981

Number of Shrimp/Station

Station	‹103	›103	Totals
3	2263.09	1430.60	3693.69
4	4729.62	2900.38	7630.00
7	1263.13	2234.19	3497.32
10	4543.11	3889.76	8432.87
11	1392.89	2347.37	3740.26
13	2293.85	2031.47	4325.33
14	1581.09	2533.29	4114.38
15	757.12	1161.88	1919.00
17	1164.81	1334.86	2499.67
18	690.38	1133.52	1823.90
20	729.25	855.75	1585.00
5	1769.08	1731.70	3500.78
6	476.09	311.91	788.00
8	289.48	579.52	869.00
9	15.51	77.49	93.00
12	283.91	978.65	1262.56
16	140.65	679.01	819.66
19	769.87	1378.50	2148.37
21	1039.07	957.63	1996.70
22	13.98	409.82	423.80
23	1259.51	664.54	1924.05
24	1270.52	1354.63	2625.15
Inside	21408.35	21853.07	43261.42
Outside	7327.66	9123.41	16451.08
Total	28736.01	30976.48	59712.50

Cruise IV, December 1981
Number of Shrimp/Station

Station	‹103	›103	Totals
3	792.32	2864.68	3657.00
4	529.68	815.82	1345.50
7	446.55	1191.95	1638.50
10	1727.84	2819.16	4547.00
11	740.66	2404.67	3145.33
13	461.29	3044.00	3505.28
14	807.20	1709.80	2517.00
15	989.74	1821.89	2811.63
17	1082.56	3583.10	4665.66
18	356.06	1378.44	1734.50
20	1133.10	1827.40	2960.50
5	600.48	2006.52	2607.00
6	341.18	1409.82	1751.00
8	1025.72	2272.58	3298.30
9	73.79	417.39	491.18
12	86.65	456.35	543.00
16	39.31	1082.69	1122.00
19	150.69	609.72	760.42
21			
22			
23	393.22	821.99	1215.21
24	147.96	302.46	450.42
Inside	9067.00	23460.90	32527.90
Outside	3494.33	11463.87	14958.20
Total	12561.33	34924.77	47486.10

Cruise V, January 1982
Number of Shrimp/Station

Station	‹103	›103	Totals
3	492.92	584.58	1077.50
4	854.05	1077.35	1931.40
7	3099.69	3876.97	6976.67
10	3736.68	3759.66	7496.35
11	3670.93	3369.07	7040.00
13	4476.59	2557.19	7033.78
14	3169.21	2290.79	5460.00
15	3229.21	1599.12	4828.33
17	4991.95	2254.38	7246.32
18	6963.36	1782.26	8745.63
20	4132.90	907.10	5040.00
5	4712.63	1761.11	6473.74
6	582.00	849.30	1431.30
8	1778.62	628.28	2406.90
9	223.44	398.21	621.65
12	546.34	284.86	831.20
16	452.35	585.18	1037.53
19	1285.69	860.64	2146.33
21	4041.54	1277.79	5319.33
22	3972.04	1985.68	5957.72
23	3746.85	1183.49	4930.33
24	1007.93	732.91	1740.85
Inside	38817.51	24058.47	62875.98
Outside	22349.44	10547.45	32896.89
Total	61166.95	34605.91	95772.87

Cruise VI, February 1982
Number of Shrimp/Station

Station	<103	>103	Totals
3	2780.93	2178.75	4959.69
4	1214.14	937.14	2151.29
7	2333.11	2379.95	4713.06
10	2792.80	2085.35	4878.16
11	251.77	375.16	626.93
13	1534.42	1406.78	2941.20
14	1113.67	1399.33	2513.00
15	1055.59	969.18	2024.77
17	1919.43	1167.57	3087.00
18	805.57	690.43	1496.00
20	1561.88	592.93	2154.82
5	1005.82	1274.76	2280.59
6	332.21	329.46	661.67
8	230.24	421.38	651.62
9	264.58	359.24	623.82
12	232.00	310.71	542.71
16	267.38	672.16	939.55
19	435.18	250.68	685.85
21	478.77	116.83	595.60
22	600.52	474.98	1075.50
23	1971.27	656.48	2627.74
24	823.12	437.78	1260.90
Inside	17363.32	14182.59	31545.90
Outside	6641.09	5304.47	11945.56
Total	24004.41	19487.05	43491.46

FIGURES

TABLES